Sky and TELESCOPE

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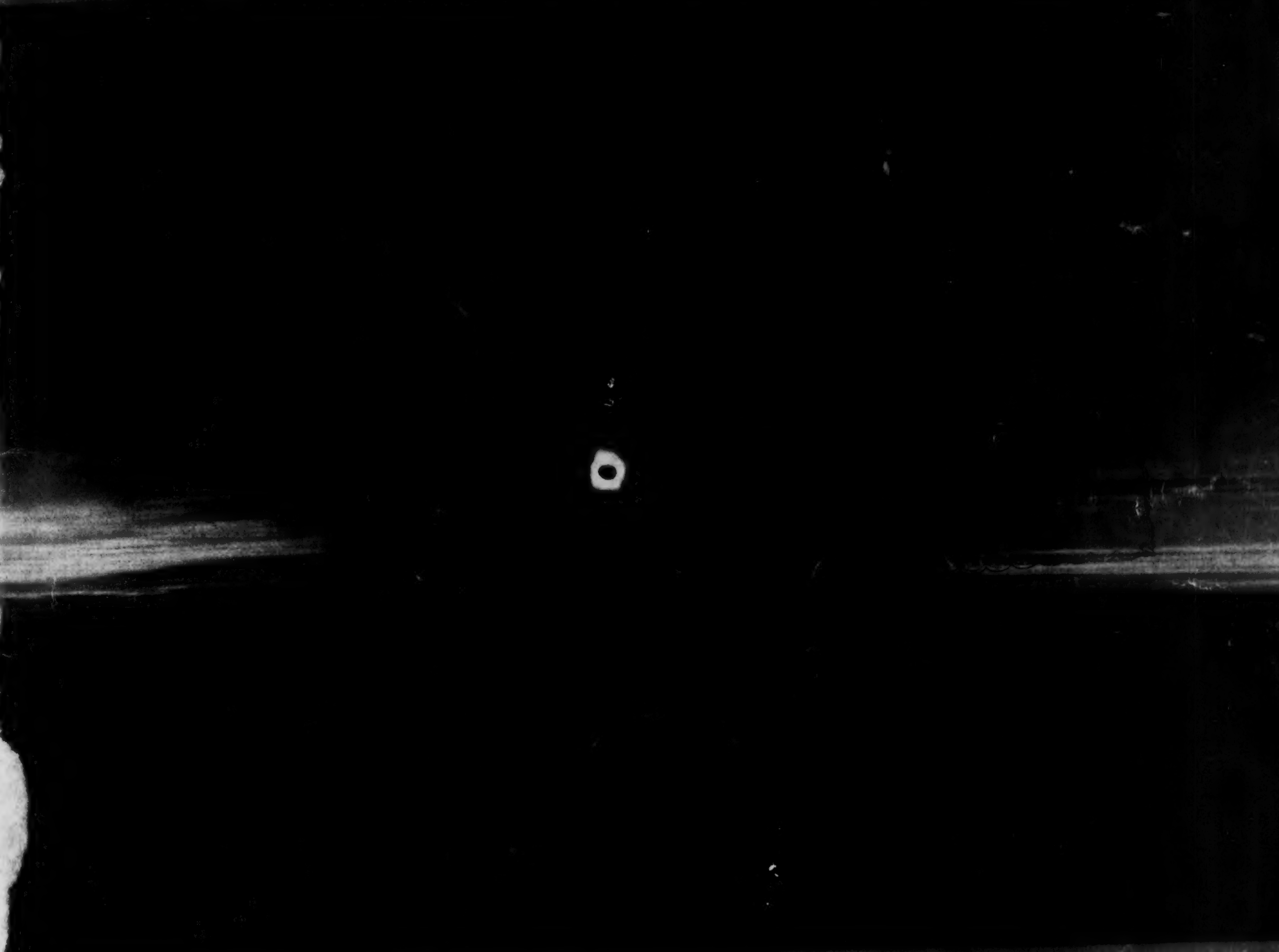

Total eclipse and shadow

In This Issue:

Vol. XIX, No. 1
NOVEMBER, 1959
50 cents

Swain


the eye to rely on

Sky and TELESCOPE

CHARLES A. FEDERER, JR., *Editor*
JOSEPH ASHBROOK, *Technical Editor*

Vol. XIX, No. 1 NOVEMBER, 1959

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COVER: The October 2nd total eclipse of the sun, as seen above the eastern horizon from an American Airlines plane at 21,000 feet, 16 miles off the Massachusetts coast. Surrounding the sun is the silvery corona, showing the relatively round form typical in years when sunspots are most numerous. The shadow of the moon on the atmosphere is conspicuous in this picture, the bright clouds at the right and left being on the edges of the narrow cylinder of totality. Photograph by Edward F. Carr, courtesy of the Boston "Globe." (See page 4.)

SKY AND TELESCOPE is published monthly by Sky Publishing Corporation, Harvard College Observatory, Cambridge 38, Mass. Second-class postage paid at Boston, Mass.

Subscription: $5.00 per year in the United States and possessions; $9.00 for two years; $13.00 for three years. To Canada, Mexico, and all countries of the Pan American Postal Union, $6.00 for one year; $11.00 for two years; $16.00 for three years. To all other foreign countries, $7.00 for one year; $13.00 for two years; $19.00 for three years. Canadian and foreign remittances should be made in United States currency. Single copy 50 cents. Back numbers, as available, 50 cents each.

All notices of change of address must be sent one month in advance and accompanied by old and new addresses. When sending your renewal order, or writing in regard to your subscription, your current mailing address must be given. Return our bill form with renewal payment. Circulation manager, Nancy R. Bolton. Office staff: Janet G. Condon, Virginia K. Cox, J. Caroline Nason, Mary Silva, John Simmons, Helen B. Sniegiecki, Stacia Strong.

Editorial and advertising offices: 49-50-51 Bay State Rd., Cambridge 38, Mass. Advertising rates are listed in STANDARD RATE AND DATA SERVICE, or sent upon request. Advertising manager, Henry M. Corrado. Editorial staff: Francis B. Russell, William E. Shawcross, Donald B. Silverman.

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Some New American Radio Telescopes

To many astronomers, the 1950's will be remembered as the decade of an explosively rapid expansion in radio astronomy, when nearly every branch of the science was invigorated by the findings with giant instruments of varied designs. An even faster growth in the near future is promised by additional large radio telescopes just completed or under construction in this country.

On October 7th, the University of Michigan dedicated the new 85-foot paraboloidal radio telescope at its Peach Mountain station, 16 miles northwest of Ann Arbor. Primarily intended for solar research, the 155-ton instrument joins a 28-foot antenna that has been at work there since August, 1957. Being fully steerable, the equatorially mounted 85-foot dish can track the sun from rising to setting.

This instrument will also be used for 21-centimeter and other studies of Milky Way and extragalactic sources. Many refinements are incorporated, including a newly developed broad-band traveling-wave-tube radiometer, representing a major advance over other similar receivers. It will permit observations to be made at wave lengths as short as three centimeters. Another feature is a ruby maser, a virtually noise-free amplifying device. The project has been supported by the Office of Naval Research.

Another 85-foot radio telescope is planned to be in operation by June, 1960, at the University of California's Hat Creek station in the Lassen National Forest, in northern California. The 60-acre tract, 14 miles southeast of the town of Burney, was selected after a five-month survey of 30 possible localities. A second paraboloidal antenna, 33 feet in diameter, is expected to be in use at the same site next month. Harold F. Weaver is director of the new radio observatory, which will cost about $500,000. ONR is providing 70 per cent of the amount, and will share the operating expenses with the University of California.

Much larger than these instruments is the 140-foot dish under construction at the National Radio Astronomy Observatory at Green Bank, West Virginia. On page 26 of this issue, NRAO astronomer Frank D. Drake reviews the functions of radio receivers and explains the importance of radiometer design in the operation of radio telescopes.

Thirty airline miles away, at Sugar Grove, West Virginia, the Naval Radio Research Station is constructing the largest steerable radio antenna of all, a 600-foot paraboloid. Although it is designed primarily for military communications research, it will also be used for basic astronomical work.

ECLIPSE OVER NEW ENGLAND

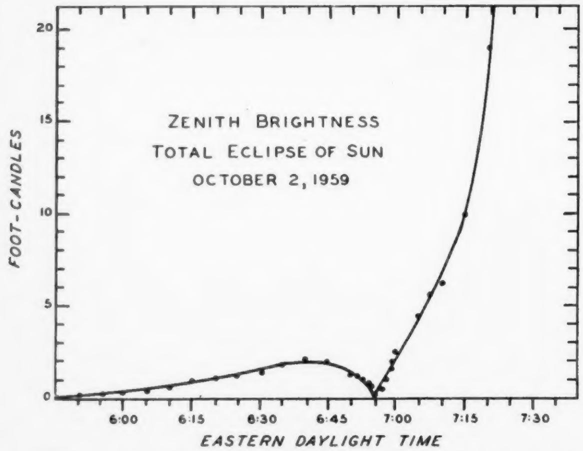
This series of eclipse pictures was taken from an airplane by David H. Freeman, Massachusetts Institute of Technology, aided by John S. Robie, Lexington, Massachusetts, and John A. Griner, Harvard Business School. The plane was flying some 120 miles an hour at 6,500 to 6,800 feet when these pictures were made.

Dr. Freeman used two Leica cameras, with 135-mm. lenses and ultraviolet filters. One camera, containing Kodachrome film, was preset for the partial phases, and secured the topmost picture, of the thin rising crescent before totality. The other camera, with high-speed Ektachrome (ASA 160), took the totality shots, the diamond-ring effect, and the early partial phase (bottom).

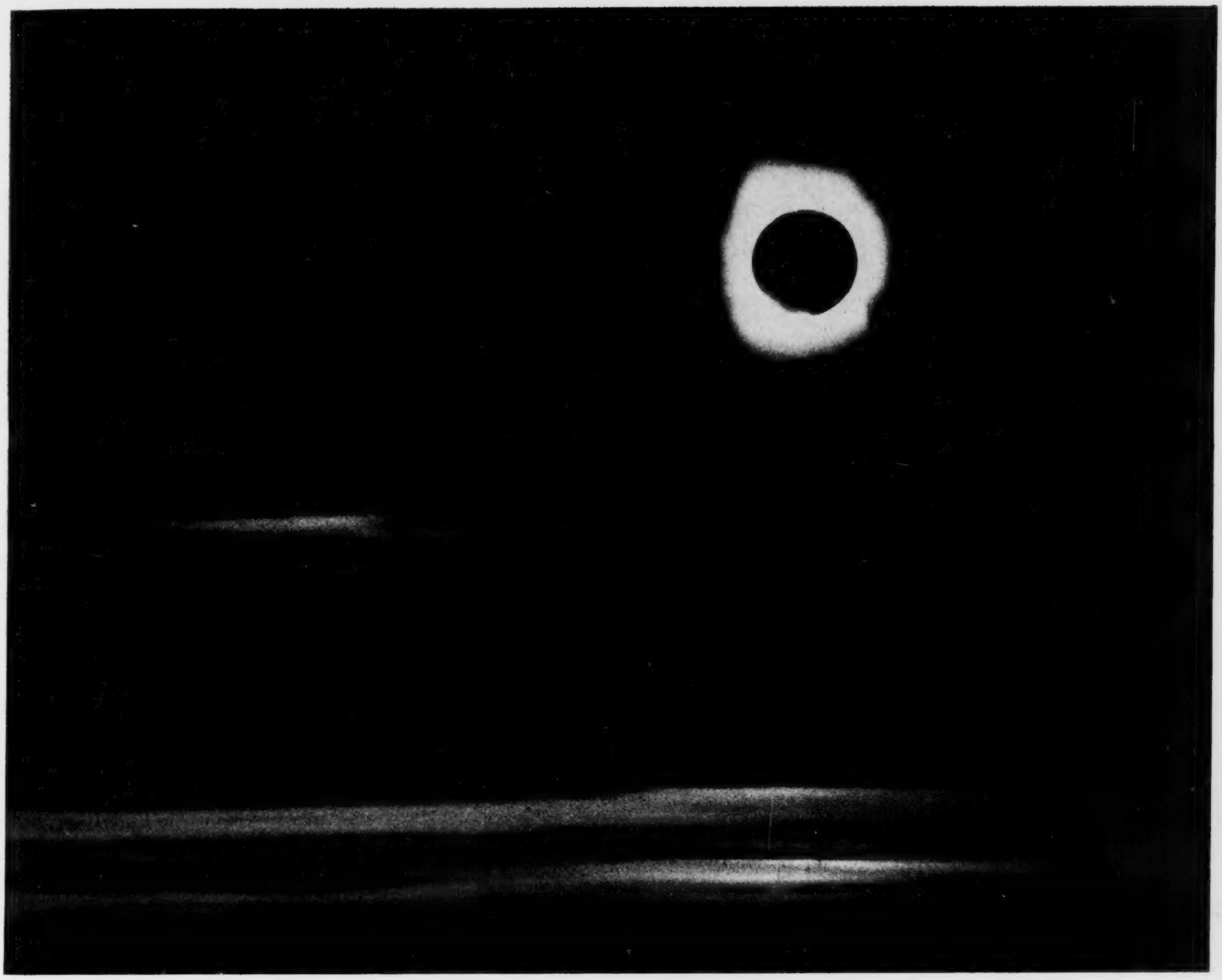
AT MOST a few hundred observers, borne aloft in airliners and small private planes, saw the total phase of October 2nd's dawn eclipse in the United States. Meanwhile rain, fog, and cloudy skies disappointed many thousands of ground observers who flocked to shore sites north of Boston and inland vantage points in Massachusetts and southern New Hampshire.

By 9 o'clock that morning the sun was shining brightly at Salem, where 500 observers had gathered for the SKY AND TELESCOPE eclipse party at the Coast Guard Air Rescue Station and the Plummer Home for Boys. But at 6:50 a.m., Eastern daylight time, when the moon's shadow briefly touched New England, these travelers from 25 states and five foreign countries were standing in a dismal rain with visibility less than a mile. The remnant of Hurricane Gracie, passing northward across New York State and western New England, was too slow in moving out of the eclipse area. No report has been received that any ground observer in North America saw the total phase.

Photography was possible only from the air. Probably the highest observer was J. Allen Hynek, Smithsonian Astrophysical Observatory, who was in a jet trainer



Observing near Lynn, Massachusetts, Armand N. Spitz, of Yorklyn, Delaware, was able to secure this record of the changes in zenith brightness on eclipse morning. He used a Weston photoelectric photometer, making observations every five minutes until near totality. The sudden darkening experienced by ground observers is shown by the curve, as well as the rapid increase in brightness thereafter. When the partial eclipse was over, the heavy overcast gave a reading of about 45 foot-candles.



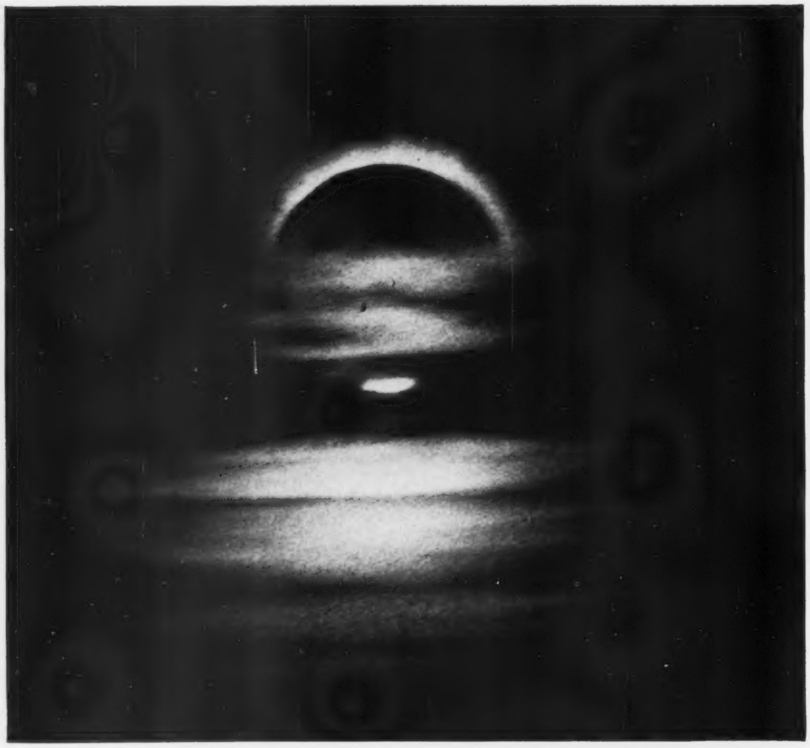
A somewhat globular corona is shown by this picture, taken from an American Airlines plane at 21,000 feet by David Wurzel, New England picture manager of United Press International Photos. He used a 4-by-5 Speed Graphic with a 15-inch lens, exposing 1/125 second on Royal Pan film with no filter. Note the reflection of coronal light from the layer of clouds.

at 35,000 feet, where the eclipse was "perfect, except for a few little streaky clouds." Several airlines sent up large planes, carrying scientists and newspaper photographers, some of their pictures being shown here and on the front cover.

One amateur astronomer, David H. Freeman, a physical chemist at Massachusetts Institute of Technology, had chartered a plane a month ahead of time, only to find it on eclipse morning carefully stowed away in a hangar at Bedford airport, behind a large bomber! After some hasty searching, he found another plane for his small party. Piloted by Frank D. Comerford, an instrument flying instructor, the twin-engine Apache was among the few that succeeded in breaking through the storm into clearing skies a mile or so high. As totality came, they saw the moon's shadow racing across the cloud layer below them.

The city of Boston, within the totality zone, was plagued by early morning traffic jams as tens of thousands of would-be observers sought vantage points. Large numbers crowded Lynn Beach, where the

About 25 times as many observers as in this picture attended the eclipse party at Salem, Massachusetts. Here they gaze forlornly across Salem Harbor past the lighthouse at old Ft. Pickering, while the rain comes down. Marblehead is in the distance. Much photographic and telescopic equipment was set up here, including an elaborate array by the Grumman Astronomical Society of Bethpage, New York. United Press International photographs.



Above: The total eclipse seen from a Northeast Airlines plane at 16,000 feet by Frank Curtin, an Associated Press photographer. He used a Hasselblad camera with a 180-mm. lens. Wide World photograph.

Right: A multiple exposure of four phases of the partial eclipse, taken atop the R. C. A. building in New York City. Exposures were made at five-minute intervals from 7:25 a.m. (bottom to top), 1/1,000 second at f/22 with an orange filter. Wide World photograph.

Amateur Telescope Makers of Boston had their official station, and thronged to Winthrop, Revere, and Cape Ann. On Nahant, the American Association of Variable Star Observers set up their instruments within the grounds of the U. S. Army's Nike rocket base.

Inland, at Mt. Wachusett, observing teams from the Detroit Astronomical Society, the Smithsonian Astrophysical Observatory, the Boston Museum of Science, and the Air Force Cambridge Research Center, were stationed. With hundreds of other watchers, their pre-dawn hopes were raised by breaks in the cloudy mantle, but during the crucial moments of totality the eastern horizon was completely obscured.

The party led by Peter A. Leavens, of Freeport, New York, arrived at Salem early, then decided to search for better weather. They found a vantage point near Nashua, New Hampshire. During totality, which was hidden by clouds, they saw the bright sky to the north outside of the shadow path.

Arthur Stockellburg, W1SS, of Lincoln, Massachusetts, was one of several amateurs who co-operated to make successful radio observations of the effects of the eclipse. He transmitted an unmodulated, constant-intensity 3,820-kilocycle signal, which was monitored at Westfield, Massachusetts; Ellsworth, Maine; Springfield, Vermont; and other points. The Westfield record showed a short-lived sharp rise in signal strength during totality; other stations reported a broad peak.

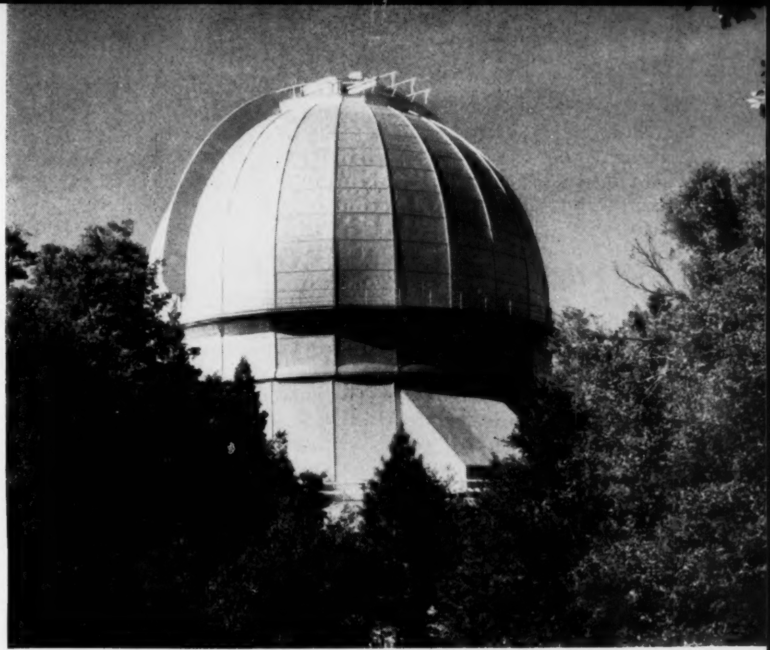
First reports from American observers outside the totality zone indicate that clouds also interfered with seeing the partial phases. In New York City, the best view came about 7:30 a.m., when some one-fourth of the sun's diameter was covered by the moon.

From early information, even parts of the highly favored Canary Islands had clouds, possibly affecting some expeditions adversely. Perhaps the most dramatic view of the eclipse was obtained by the crew of a jet F-101B Voodoo, which raced the moon's shadow for seven minutes from Fuerteventura Island to the African desert at a speed of 1,080 miles per hour. During the flight, a magnetic tape recorded measurements of polarization in the sun's corona, planned as a test, particularly in the infrared, of the presence of synchrotron radiation in the outermost solar atmosphere.

Reflections of a Spectroscopist

OTTO STRUVE

*National Radio Astronomy Observatory**



The dome of the 100-inch Hooker reflector at Mount Wilson Observatory as it looks today. In use since 1918, for three decades this was the world's largest telescope. Its enormous light grasp particularly suits it for spectroscopic work. The room of the high-dispersion coude spectrograph is located under the slanting roof, at the southern end of the polar axis.

SINCE my recent appointment to the staff of the National Radio Astronomy Observatory, I have been thinking a great deal about some of the questions raised at a symposium in Paris last July. There, under the same title as this article, P. Swings, of the University of Liège, made an eloquent appeal to young French scientists to develop an interest in stellar and nebular spectroscopy, in order to take advantage of the fine instrumental facilities now available to them at St. Michel Observatory.

As Professor Swings pointed out, "The study of spectra of the celestial objects seems to have lost some of its appeal during the past few years, due to the emergence of accurate photometric methods, of radio astronomy investigations, of semitheoretical applications of nuclear physics, and of such recent developments as plasma physics, magnetohydrodynamics, and shock waves."

Yet, he continued, a large number of purely spectroscopic problems remain unsolved or only partly solved. "Progress in our knowledge of the Milky Way and other galaxies will, perhaps forever, depend to a large extent upon special spectroscopic investigations. We would, in fact, not have been able to go very far in our theories of stellar evolution if it had not been for the patient and admirable spectroscopic researches carried out at Mount Wilson, Palomar, McDonald, Lick, Victoria, Haute Provence, and elsewhere."

Although in turning to radio astronomy I am giving up, or at any rate greatly reducing, my work in optical stellar spectroscopy, my decision is in no sense caused by loss of interest in this field. It is one of the most rewarding branches of scientific endeavor, and I would like to urge young astrophysicists to choose it for their careers.

My first exposure to the marvels of stellar spectra occurred just 40 years ago. As a student at the University of Kharkov in Russia, I was taking an astrophysics course given by B. P. Gerasimovich, who had just returned after participating for several years in A. A. Belopolsky's spectrographic investigations at Poulkovo Observatory. Dr. Gerasimovich had brought back with him a series of spectrograms of different stars. He used these to teach his students the technique of measuring radial velocities.

My studies were interrupted by the civil war in Russia, and I was only able to resume them after arriving at Yerkes Observatory in October, 1921, as a graduate student and assistant in stellar spectroscopy to director E. B. Frost. I remember vividly how he told me that the measurement of stellar radial velocities was the most exciting, gratifying scientific occupation he had ever known!

Forty years ago the application of Doppler's principle to astronomy was still fairly new. Many astronomers then living had personally known Huggins, Vogel, and other pioneers in the measurement of the line-of-sight motions of stars, and could recapture the almost mystical delight brought by this great scientific advance. Frost, Belopolsky, W. S. Adams, J. S. Plaskett, and W. W. Campbell belonged to that period. But to me, of a later generation, the excitement that these men felt was foreign: I recognized the great importance of determining radial

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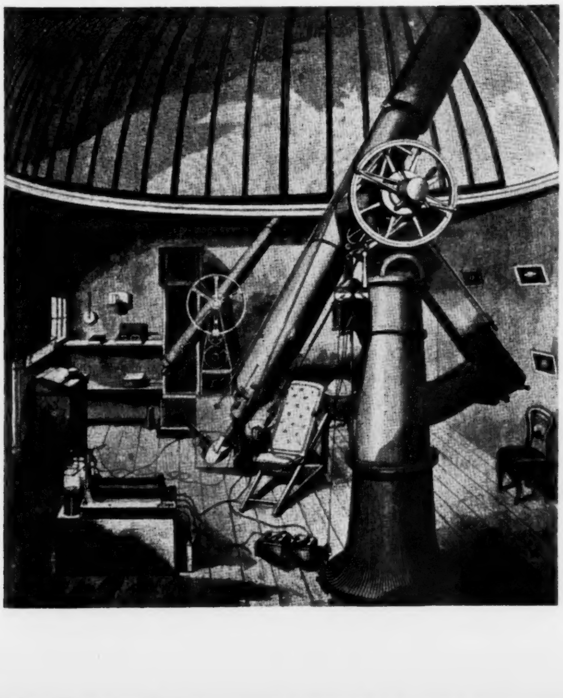


The first observatory especially devoted to spectroscopic studies of heavenly bodies. From 1860 to 1869, William Huggins used this 8-inch Clark refractor at Tulse Hill, England, for visual observations of the spectra of stars and nebulae. Huggins in 1868 was the first to attempt to measure the line-of-sight velocities of stars. From H. C. King, "The History of the Telescope."

velocities of stars, but the application of Doppler's principle to astronomy seemed an old story.

Perhaps today many young astronomers regard the more recent developments of stellar spectroscopy in the same light. Yet, I have experienced the same kind of exhilaration as did Frost in his radial velocity work, for I have witnessed enormous advances, such as A. S. Eddington's proof that sharp absorption lines of ionized calcium and neutral sodium can be produced in interstellar space; M. N. Saha's theory of excitation and ionization, and its extension by H. N. Russell, E. A. Milne, and others; Cecilia Payne Gaposchkin's application of this theory to stellar spectra; A. Unsöld's derivation of abundances of chemical elements in the atmospheres of stars, and many more.

But this very feeling comes in other ways. Ever since obtaining my first stellar spectrogram with the 82-inch telescope at McDonald Observatory, I have not spent a night observing there, or during the past nine years at Mount Wilson, without experiencing excitement and anticipation. Never have I returned from an observing visit at either place without some new and usually unexpected features on some of my spectrograms. The predicted characteristics were not always there; the unexpected ones made every spectrogram a potential gold mine!

To achieve important results it is necessary, as Swings said, "to keep abreast of all technical advances, and all new theoretical developments. . . . The spectroscopist must first seek to increase the range of wave lengths he can cover, and to shorten the time required to record a spectrum by increasing the sensitivity of his receivers." Although many important spectroscopic problems can be attacked with relatively small reflectors and simple, medium- or small-dispersion spectrographs, the scope of the work may be so limited that frustration might destroy the investigator's initiative.

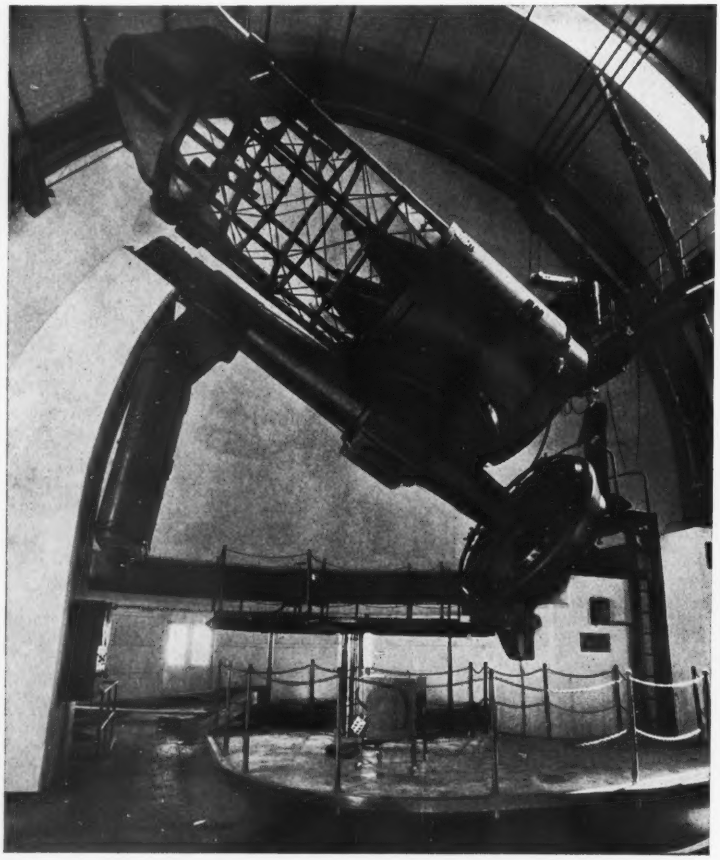
I experienced this frustration at Yerkes. The combination of the 40-inch refractor and a very old spectrograph, employing three 60-degree prisms of optically dense glass, allowed me to reach stars no fainter than 4th or 5th magnitude with a linear dispersion of 10 angstroms per millimeter. Today, a 60-inch parabolic reflector and a modern grating spectrograph, with a range of dispersions between 10 and perhaps 75 angstroms per millimeter, should normally be regarded as the minimum instrumental requirement, except for such spectral classification programs as those undertaken by W. W. Morgan and P. C. Keenan, or by D. Chalonge in France.

Edwin B. Frost (1866-1935), second director of Yerkes Observatory, devoted his entire career to stellar spectra. From his autobiography, "An Astronomer's Life," Houghton Mifflin Co., 1933.

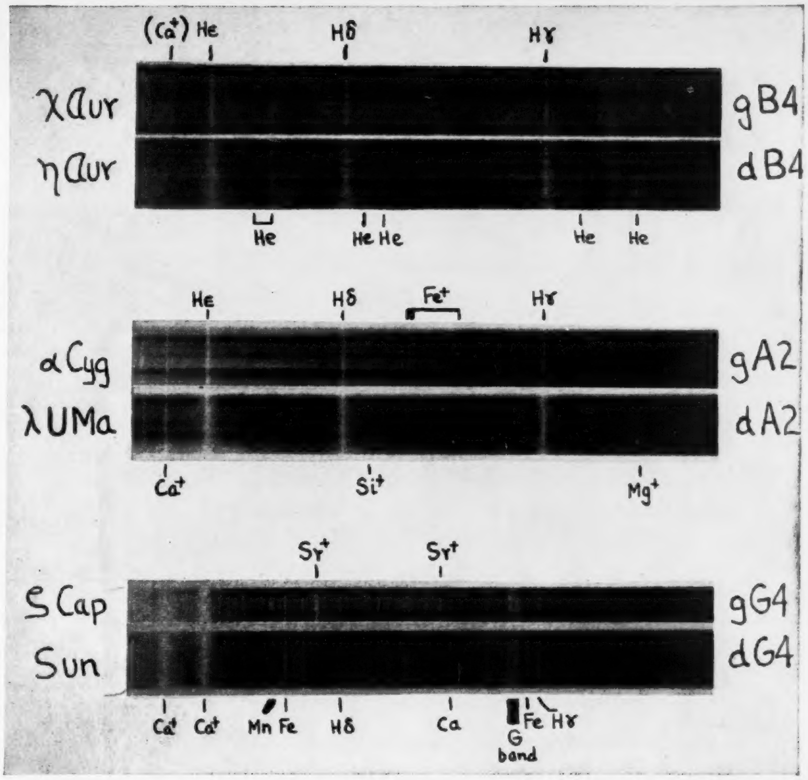
Photographic procedures are still good for many problems, but the spectroscopist should try to develop other methods. B. Strömgren has been very successful in measuring the intensities of absorption lines using a photoelectric photometer with narrow-transmission-band filters. At Mount Wilson, a promising method of scanning spectra has been developed by L. Spitzer, Jr., and his collaborators, and a somewhat different technique by O. C. Wilson and J. B. Oke.

Spectroscopists can profitably exploit and improve the image-tube methods of A. Lallemand, W. A. Baum and J. S. Hall, or W. A. Hiltner. Because the image tube promises to reduce the time required for recording the spectrum of even a faint star to minutes or seconds, this device should be well suited for observing certain very rapid changes in stellar spectra. I have described some of these short-lived events in my article on Nova Herculis in the July issue, and the one on flare stars in September.

A problem of this nature that has intrigued me for many years is in connection with the famous eclipsing binaries U Cephei and U Sagittae, when only a narrow crescent of the early-type component is unhidden just before or after totality. My McDonald spectrograms show during these brief intervals extraordinary changes in the absorption lines of the star undergoing eclipse. But the exposure times were too long to record the changes without serious contamination by the light of the late-type subgiant producing the eclipse. The use of image-tube techniques should be especially profitable in this case.



The 82-inch reflector of McDonald Observatory on Mt. Locke, Texas, was completed in 1939. This fine instrument has been very effective for astrophysical observations. Note the counterweight close to the northern pier, as well as the observing platform in the background.



Spectral differences between giant and dwarf stars are shown in these spectrograms by W. W. Morgan, Yerkes Observatory. The upper spectrum in each pair is that of the giant. In the two B4 stars, Chi Aurigae has much sharper hydrogen lines than the dwarf Eta Aurigae. There is a similar contrast between the spectra of Alpha Cygni (Deneb) and Lambda Ursae Majoris. Ionized strontium lines are stronger in Zeta Capricorni than in the sun.

Professor Swings also recommends efforts to observe with reasonably high dispersion the infrared spectral region between one and 15 microns. In addition, he would like to see someone try M. Czerny's evaporograph technique, in which long-wave radiation is detected by its heating effect upon some highly volatile material, such as a very thin film of camphor. Others should attempt to bridge the gap between the optical infrared, which extends to about 15 microns, and the present short-wave limit of ground-based radio telescopes at about two or three centimeters. This will, of course, require a radio instrument located in a satellite above the ionosphere, a region which is opaque in the range of wave lengths mentioned.

Satellite instruments should soon be informing us of the appearance of stellar spectra at wave lengths shorter than 3000 angstroms. Preliminary calculations by L. Aller indicate, however, that in the far ultraviolet the absorption lines of the Lyman series of hydrogen and the Lyman continuum, both produced by interstellar atoms, may be so strong that even the nearest stars will be invisible at wave lengths below 1300 angstroms. But there should be much to learn from spectra between the first line in the Lyman series – Lyman alpha – and the present ultraviolet limit imposed by our atmosphere at about 3000 angstroms.

It was a revelation to most spectroscopists when recent solar spectrograms that were obtained by the Naval Research Laboratory (SKY AND TELESCOPE, July, 1959, page 496) turned out to be full of emission lines in the far-ultraviolet region. After this discovery had been made, it was easy to explain the phenomenon, but to my knowledge no one had clearly predicted a similarity between the solar spectrum from 1500 to 2500 angstroms and the emission-line spectra of such stars as Z Andromedae at the usual photographic wave lengths.

Perhaps the most exciting problem in stellar spectroscopy today is the determination of abundances of chemical elements in the atmospheres of stars. We now realize that these abundances are not the same in all stars, and many of the more striking differences have been attributed to evolutionary processes. But I believe that we are beginning to wonder whether chemical abundances are *exactly* the same in *any* two stars.

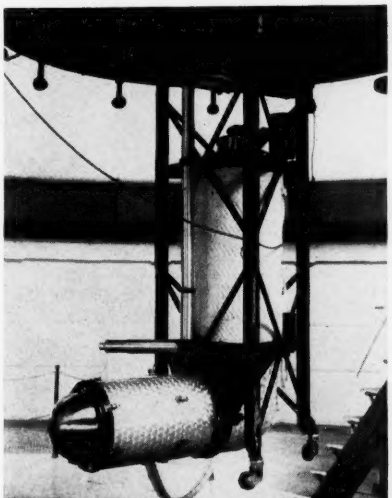
It is true that the spectrum of the sun can be quite closely matched by spectra of a large number of other stars of similar surface temperature and luminosity. This resemblance is partly due to the multitude of absorption lines produced by atoms of neutral iron, which are prominent features in the spectra of stars like the sun. But on examining the lines of other, less common elements, we almost always find small differences, often too delicate for visual discrimination on the spectrograms, and detectable only by refined spectrophotometric techniques. When photography has been replaced by photoelectric scanning, a large field of study will be opened, and every star, even the brighter ones, will probably reveal remarkable differences in composition.

To illustrate what has already been achieved with spectra of relatively small dispersion, let me describe some work on differences in chemical composition among stars of spectral classes *F* to *K*. This material has been adapted from a chapter by Margherita Hack of Merate Observatory, Italy, in a forthcoming joint textbook on stellar spectroscopy.

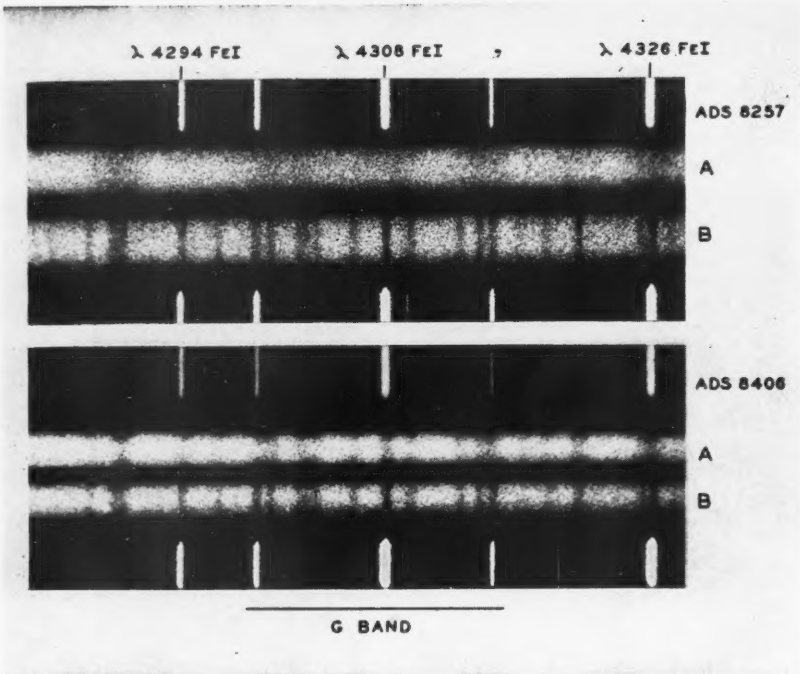
In 1950 and 1952, Nancy G. Roman published a study of several hundred stars of spectral classes *F*4 to *K*5. These were divided into two nearly equal groups according to whether the absorption lines of metals appeared to be weak or strong. This was followed by P. Wellmann and Miss Hack's finding that in the stars with weak lines the molecular band due to CH is more intense than in strong-line objects.

The weak-line and strong-line stars show other differences. Because metallic absorption lines tend to be more numerous in the violet region than in the green and yellow, we should expect weak-line stars to show less "blanketing" of the violet continuous spectrum, and they should appear bluer than strong-line stars of similar spectral types. Miss Hack finds that this is apparently the case.

Miss Roman had also noticed that the weak-line stars usually have much larger



This two-prism spectrograph is used at the Cassegrainian focus of the 82-inch McDonald reflector pictured on the facing page.



Rapidly rotating stars can be recognized by their widened spectral lines, as illustrated by these spectrograms of two double stars. In each pair, the brighter component (labeled A) is rotating faster than the fainter star (B), which consequently has sharper lines. Otherwise, the spectra are similar. In ADS 8257, the primary has an axial rotation of perhaps 100 kilometers per second. Mount Wilson spectrograms by the author.

space motions than those with strong lines. She did not use space motions as a criterion for attributing the stars to one or the other group. Martin and Barbara Schwarzschild, on the other hand, investigated spectra of stars selected by their kinematical properties. Similar studies have been made by J. L. Greenstein and Keenan, and by the latter and G. Keller. All of their results, while differing in details, were quite consistent with the previous work.

Apparently, in this range of spectral types there are three groups of stars. In one, the metal abundances are somewhat larger (about two times) than in the "normal" group; in another they are slightly smaller. In the latter group, absorption bands of CH and perhaps CN are relatively strong. These weak-line stars are often identified with Population II, while "normal" and strong-line stars belong to Population I.

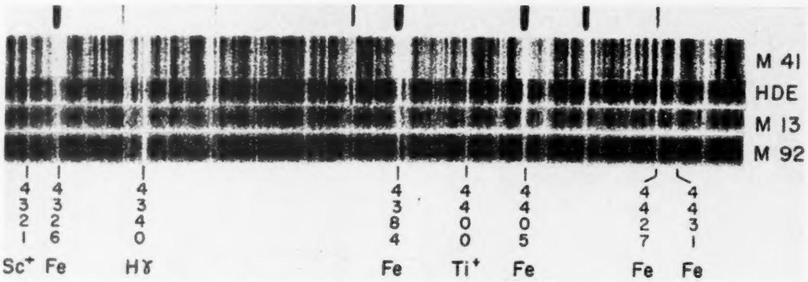
Is there a sharp distinction between these groups? Apparently not. Miss Hack says that although "there is a strong correlation between spectroscopic features and kinematical properties, there are some high-velocity stars which do not show spectroscopic peculiarities, and there are also low-velocity stars that do." She therefore believes that there is a continuous range of chemical compositions from conspicuously low abundances of elements heavier than hydrogen to noticeably high abundances of the same elements. This, in turn, might mean that among the stars of spectral types *F*5 to *K*5 all ages are represented, from the oldest, Population II with extreme weak-line character, to the youngest, Population I with very strong lines.

Such a diversity in the ages of main-sequence stars is not unexpected. The oldest were formed when the interstellar medium contained mostly hydrogen and few metallic atoms. The youngest were created after the interstellar gas had been enriched with heavy elements by the escape of matter from supergiants, novae, and supernovae. However, a marked difference in the ages of giants is not so easily explained. There is every reason to believe that giants in a galactic cluster like the Hyades are younger than those in a globular cluster or a very old galactic cluster, such as M67. But it is not yet certain that we can directly correlate spectroscopic features of giants in the general field of the Milky Way with their ages.

Some of the most recent work on chemical abundances, based upon the best existing spectrograms from Mount Wilson and Palomar Observatories, has been published in the March and May, 1959, issues of the *Astrophysical Journal*. G. Wallerstein and H. L. Helfer find that two G-type stars in the Hyades cluster have the same abundances (within 25 per cent) as the sun for sodium and nine heavier elements. Barium may be slightly overabundant, as a result of element building in the stellar interiors. But these results indicate that, in general, between the time that the sun was formed (five billion years ago) and the origin of the Hyades (one billion years ago), there has been little, if any, change in the composition of the interstellar medium.

On the other hand, extremely old Population-II stars show marked metal deficiencies compared to the sun and younger objects. Helfer, Wallerstein, and Greenstein have studied two globular-cluster giants and one high-velocity giant star not belonging to a cluster (HDE 232078), the metal deficiency factor being 20 in two cases and at least 100 in the third (a star in M92). A *K*-type giant in the relatively young galactic cluster M41 (about a hundred million years old) gave roughly the same abundances as the sun. In the old, high-velocity star 85 Pegasi, a visual double, the elements from sodium upward are less abundant than in the sun by factors of three to nine.

These are challenging studies. Persons not acquainted with the many observational and theoretical difficulties involved in these determinations may be surprised that the results are so uncertain. The reason is not imperfect observations and measurements, but the complex process of ascertaining the excitation and ionization of the stellar atmosphere, as well as its turbulence, before the atomic abundances themselves can be computed.



Spectra of four K-type giant stars showing differences in chemical composition. At the top, a star in the galactic cluster M41 has much stronger metallic lines than does the high-velocity star HDE 232078 or two stars in the globular clusters M13 and M92. The hydrogen-gamma line is similar in the four cases, but there is great weakening of the ionized scandium, iron, and ionized titanium lines in the lower spectra. These Palomar spectrograms by H. L. Helfer, G. Wallerstein, and J. L. Greenstein, are courtesy the "Astrophysical Journal."

OBSERVING THE SATELLITES

Touching the Moon

THE first man-made object to reach the surface of the moon was the Soviet space probe that landed on September 13th at 21:02:23 Universal time. The 860-pound spherical instrument package and the 3,331-pound final-stage rocket both struck the target, according to Soviet tracking data.

Despite the incompleteness of information about this historic operation, the great accuracy with which it was performed is evident. For a probe to strike the moon after about 35 hours of flight, the speed of the final stage at burnout must be within 200 feet per second of an intended value of approximately 35,700 feet per second. Furthermore, the trajectory after burnout may not differ by more than half a degree from an angle of 12 degrees with the horizontal. In addition, since the earth is a rotating platform, actual launching has to occur within a fraction of a minute of the predetermined moment, unless course corrections are possible during flight. The success of Lunik II shows that these stringent requirements were met.

Very little has been announced concerning the multistage rocket itself. From the weights of the last stage and instrument package, it is evident that at least half a million pounds of rocket-engine thrust had been employed.

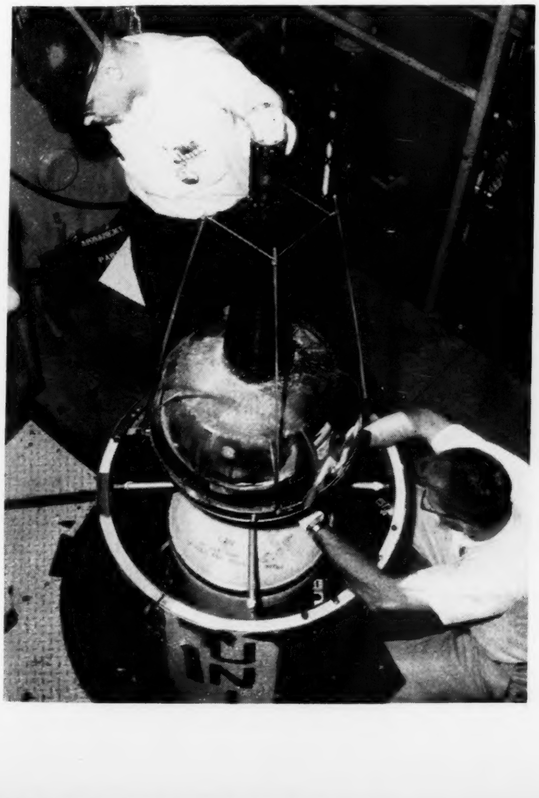
Inside the probe were radio transmitters, operating at three frequencies of 19.993, 39.986, and 183.6 megacycles. When the probe was so close to the moon that it was being speeded up by lunar gravity, observers at the 250-foot Jodrell Bank radio telescope in England noted the expected Doppler change in signal frequency. The signals ceased abruptly at 21:02:24 UT. With an allowance of $1\frac{1}{4}$ seconds for the time of transmission from the moon, the impact time was only 83 seconds later than the predicted 21:01, announced many hours earlier by Soviet scientists. This close agreement is an indication of the great accuracy of the early tracking from which the forecast was made. American and Japanese radio observers also reported successful tracking operations, but the moon was below the horizon for practically all of the United States at the moment of impact.

Like the earlier Russian lunar probe of January 2, 1959, which missed the moon and entered into orbit around the sun, the September capsule ejected a cloud of luminous sodium vapor, at 18:39 UT on September 12th. Seen from the earth, at a distance of less than 100,000 miles, the short-lived "artificial comet" was located at right ascension $20^h\ 41^m$, declination $-7°.2$. At the time, this part of the sky was unobservable in America, but the luminous cloud was photographed at six or more Soviet observatories.

There appears to be no hope whatever of recognizing the impact crater on the moon caused by the fall of the probe. According to G. P. Kuiper, the craterlet would be only about 100 feet in diameter and with walls 10 feet high, thus lost among the multitudes of tiny uncharted pits that dot the lunar surface. The dust cloud thrown up by the impact might have been detectable. Press accounts of a cloud lasting 58 minutes that was seen by a Hungarian watcher are probably erroneous, as any dust would have fallen back much sooner, lacking the support of an appreciable lunar atmosphere. Details are unavailable concerning the photographs said to have been taken at Lvov Observatory in Russia, showing a cloud immediately following impact that had not been recorded just before it.

According to the Soviet news agency Tass, analysis of the radio tracking data indicated that the point of fall was in the vicinity of the craters Archimedes, Aristillus, and Autolycus, at selenographic latitude +30°, longitude 0°. (The extent of uncertainty was not indicated.) This conclusion was based in part on the readings of a "lunar altimeter," presumably a radar device whose findings were telemetered to earth on the 183.6-megacycle channel.

Some preliminary results have been announced from the data telemetered by the probe. No indication of a lunar magnetic field was found, within the limits of sensitivity of the magnetometer in the instrument capsule. Measurements of cosmic ray flux were made along the flight path, in which nuclei of helium, carbon, nitrogen, oxygen, and heavier elements were counted.



The Vanguard III package being fitted to satellite launching vehicle 7 at the Atlantic Missile Range, Cape Canaveral, Florida, by R. J. Andryshak (left) and D. R. Corbin, both of the National Aeronautics and Space Administration. The satellite was instrumented to measure the earth's magnetic field, solar X-rays, and other conditions in space, such as numbers of meteoritic particles. This was the last ascent in the Vanguard program.

Vanguard III

THE LAST of the Vanguard series of artificial satellites, begun as an American contribution to the International Geophysical Year, was successfully injected into a low-inclination orbit on September 18th at 5:29:45 Universal time, from Cape Canaveral, Florida. This launching was sponsored by the National Aeronautics and Space Administration, which had taken over the Vanguard program from the Office of Naval Research a year ago.

The hour of launching favored optical observations in the evening sky from northern middle latitudes, and many early Baker-Nunn photographs and Moonwatch sightings were made. To most visual observers, satellite 1959η appeared as bright as a 7th-magnitude star.

During its initial revolutions around the earth, the satellite had an anomalistic period (counted from one perigee passage to the next) of 130.19 minutes. It rose to 2,330 miles above the earth's surface at apogee, and descended to 318 miles at perigee, moving in an orbit inclined $33\frac{1}{3}$ degrees to the equator. The orbital characteristics indicate a lifetime of more than 40 years for 1959η.

The 100-pound satellite consists of a 20-inch spherical instrument package, bearing a 26-inch-long conical snout, and the unseparated 50-pound final-stage rocket. The fiberglass case of the last of the three stages was intentionally left attached to the instrument compartment, in order to minimize tumbling. (When the cloud-cover satellite Vanguard II was

The components of Vanguard III. At the left are the battery packs and battery compartment lid; next, the lower three-quarters of the satellite's magnesium shell; battery pack tie rods; turn-on plugs controlling transmitter; battery gas relief valve; magnetometer electronics; magnetometer tube and upper quarter of satellite shell; X-ray and environmental electronics and tracking transmitter (sitting atop part of internal structure). In the foreground of the two electronics packages are internal equipment clamps. The pictures are from the National Aeronautics and Space Administration.

sent up on February 17, 1959, separation of the final stage gave the sphere a wobble, thereby making its photoelectric scannings difficult to interpret.) The power supply of 1959η consists of 62 silver-zinc batteries, weighing 22½ pounds in all, which are expected to function for about 90 days, this depending on temperature conditions.

One major Vanguard III experiment is the measurement of the earth's magnetic field with a new apparatus. The magnetometer is carried at the tip of the 26-inch cone, which is made of fiberglass bonded with phenolic resin, so that the sensor is separated from the metal parts and magnetic fields in the sphere.

In the operation of this device, command from a ground station causes a 6½-ampere magnetizing current to flow for two seconds through a copper coil that surrounds a container of liquid hexane. The strong magnetizing field lines up the spin axes of the protons in the hexane, and this orientation tends to persist for a few seconds after the current is turned off. During the decay of this alignment, terrestrial magnetism imposes a precession upon the protons, thereby inducing a weak current in the copper coil. After amplification, this proton-precession current is telemetered to ground. Eight Minitrack stations have similar magnetometers, for simultaneous observations at the earth's surface. Field strengths as low as 10 gammas (0.0001 gauss) can be measured with this equipment.

Another purpose of Vanguard III is to measure solar X-rays that accompany flares. A pair of ion chambers, for detecting 1-to-10-angstrom radiation, are connected to memory circuits which store the count during a full orbital revolution and then telemeter the data. The count restarts when a photocell observes the emergence of the satellite from eclipse inside the earth's shadow into sunlight. In addition, the X-ray detectors continuously transmit their information to allow detailed study of rapid changes.

Four different methods of detecting meteoritic particles are included in the satellite. The erosion of three chromium strips by bombardment is measured through changes in electrical resistance. The second method employs a cadmium-sulfide photocell behind an opaque screen of mylar and aluminum; when an impact punctures the screen, light passing through the hole is detected by the cell. In addition, there are four microphones listening for impacts. Lastly, two pressurized tanks girdle the sphere, covering about 20 per cent of its area. A differential pressure gauge indicates puncture of one or both tanks by larger interplanetary particles.

The entire array of scientific apparatus in the satellite, exclusive of batteries and supporting structures, weighs only 8½ pounds.

First Two Years of the Space Age

OCTOBER 4th marked the second anniversary of the first successful launching of an earth satellite. The table on the following page lists all known attempts to send scientific payloads into space. This listing is incomplete, for the Soviet Union has not revealed its unsuccessful launching attempts.

In four firings, a total of seven major objects launched by the Russians have entered orbits around the earth, and two long-range probes have been sent aloft. The United States has made 33 attempts, 12 of which have put 15 major objects in orbit, and of five deep-probe launchings,

Satellite and Probe Launchings During the First Two Years of the Space Age

	Launched		*Nation*	*Name and Designation*	*Status*	*Notes*
1957	Oct.	4	R	Sputnik I — 1957α2	Down about Jan. 4, 1958	Last radio signal Oct. 27, 1957. Rocket, 1957α1, down Dec. 1, 1957.
	Nov.	3	R	Sputnik II — 1957β	Down April 14, 1958	Last radio signal Nov. 10, 1957.
	Dec.	6	A	Vanguard	No orbit	First-stage malfunction.
1958	Feb.	1	A	Explorer I — 1958α	In orbit	Radio silent May 23, 1958.
	Feb.	5	A	Vanguard	No orbit	First-stage control malfunction.
	Mar.	5	A	Explorer II	No orbit	Fourth-stage ignition failed.
	Mar.	17	A	Vanguard I — 1958β2	In orbit	Solar-powered radio still operating. Rocket, 1958β1, in orbit.
	Mar.	26	A	Explorer III — 1958γ	Down late June, 1958	Radio silent June 16, 1958.
	Apr.	28	A	Vanguard	No orbit	Relays for third-stage ignition failed.
	May	15	R	Sputnik III — 1958δ2	In orbit	Solar-powered radio still operating. Rocket, 1958δ1, down Dec. 3, 1958.
	May	27	A	Vanguard	No orbit	Second-stage cutoff at wrong orientation.
	June	26	A	Vanguard	No orbit	Second-stage cutoff premature.
	July	26	A	Explorer IV — 1958ϵ	In orbit	Radios silent Sept. 9 and Oct. 6, 1958.
	Aug.	17	A	Lunar probe	Failed	First-stage malfunction.
	Aug.	24	A	Explorer V	No orbit	Midflight collision of separated stages.
	Sept.	26	A	Vanguard	No stable orbit	Second-stage thrust low. Probably completed one revolution.
	Oct.	11	A	Pioneer I	High trajectory	Reached 70,700 miles from Earth.
	Oct.	23	A	Beacon	No orbit	Payload separated from booster before burnout.
	Nov.	8	A	Pioneer II	Failed	Third stage failed to ignite.
	Dec.	6	A	Pioneer III	High trajectory	Reached 63,580 miles from Earth.
	Dec.	18	A	Atlas-Score — 1958ζ	Down Jan. 21, 1959	Radio silent Jan. 13, 1959.
1959	Jan.	2	R	Mechta — Artificial Planet 1	Solar orbit	443-day period. Radio contact to 373,125 miles. Rocket also orbiting.
	Feb.	17	A	Vanguard II — 1959α1	In orbit	Radios silent Mar. 15, 1959. Rocket, 1959α2, in orbit.
	Feb.	28	A	Discoverer I — 1959β	Down early March, 1959	Radio malfunction.
	Mar.	3	A	Pioneer IV — Artificial Planet 2	Solar orbit	407-day period. Radio contact to 407,000 miles. Rocket also orbiting.
	Apr.	13	A	Discoverer II — 1959γ	Down Apr. 26, 1959	Last radio signal Apr. 21, 1959.
	Apr.	13	A	Vanguard	No orbit	Second stage caused tumbling.
	June	3	A	Discoverer III	Probably no orbit	No telemetry after second-stage firing.
	June	22	A	Vanguard	No orbit	Pressure valve in second stage caused failure.
	June	25	A	Discoverer IV	No orbit	Insufficient second-stage velocity.
	July	16	A	Explorer	No orbit	Power supply for guidance failed. Destroyed by safety officer.
	Aug.	7	A	Explorer VI — 1959δ2	In orbit	Solar-powered radio still operating. Rocket, 1959δ1, in orbit.
	Aug.	13	A	Discoverer V — 1959ϵ	Down Sept. 28, 1959	Radio frequencies undisclosed.
	Aug.	15	A	Beacon	No orbit	Booster fueling failed; orientation wrong.
	Aug.	19	A	Discoverer VI — 1959ζ	In orbit	Radio frequencies undisclosed.
	Sept.	12	R	Lunik II	On moon	Radios ceased operation upon lunar impact Sept. 13, 1959. Final stage also on moon.
	Sept.	17	A	Transit I	No orbit	Third stage failed to fire.
	Sept.	18	A	Vanguard III — 1959η	In orbit	Radios operating.
	Oct.	4	R	Lunik III	In orbit	Radios operating. Rocket also in orbit.

This table is compiled largely from information supplied by the National Aeronautics and Space Administration. Under *Nation*, A designates American launchings; R, Russian. The U. S. S. R. has not released information on unsuccessful attempts. Dates are in Universal time.

three have returned useful information.

Our American space programs have recently been reorganized. The military work, in the hands of the Advanced Research Projects Agency since February 7, 1958, has now been largely assigned to the Air Force, giving it responsibility for developing, producing, and launching military space vehicles. Project Midas, for infrared detection of ballistic missiles, and Project Samos, a satellite reconnaissance system, are also under Air Force control. The Navy will supervise development of an orbiting navigation system under Project Transit, and the Army will handle Project Notus, a satellite communication system.

The NASA has been responsible for the civilian space program since October 1, 1958. Important in this agency's plans is a series of spaceflight vehicles: Delta, Scout, Vega, Centaur, and Nova, progressively scaled to larger and heavier space missions. When Scout is ready, perhaps in mid-1961, three British scientific satellites, now being developed by 10 teams in the United Kingdom, will be launched in a joint operation with the Americans.

The 1960 fiscal budget of the United States' space effort amounts to about 800 million dollars, of which more than 500 million is allocated to NASA.

Translunar Orbit

Early on October 4th, exactly two years after the first Sputnik launching, Soviet scientists sent a 614-pound satellite into an immensely elongated trajectory past the moon, in company with the 3,424-pound final stage of the carrier rocket. While few of the details had become available at the time of writing, it was claimed by a Russian announcement that the satellite is moving around the earth in an orbit for which the apogee distance is 292,000 miles and the perigee distance about 25,000 miles. The corresponding period of revolution is about 14 days.

Presumably the final-stage rocket, which also carries a payload of 345 pounds of instruments and batteries, is traveling in a similar orbit. An earlier Soviet report gave the closest approach to the moon as about 4,400 miles, at 14:16 Universal time on October 6th.

As seen from the moon, the satellite's path was a hyperbola, as the velocity was too great to allow capture by the moon. If, as seems probable, the probe crossed the lunar orbit before the moon arrived at the intersection point, then the probe's motion would be decelerated, shrinking its orbit and shortening the period. (The reverse effects would have occurred if the moon arrived first.)

If the orbit is actually an ellipse of this character, it will be subject to major changes, as the perturbations by the lunar and solar attractions can be very large. While predictions for such a probe offer many complications, its orbital motion will be of considerable interest to astronomers in the field of celestial mechanics. Because the probe carries solar batteries as well as chemical ones, its radio transmissions, at 39.986 and 183.6 megacycles, should permit tracking for a long time.

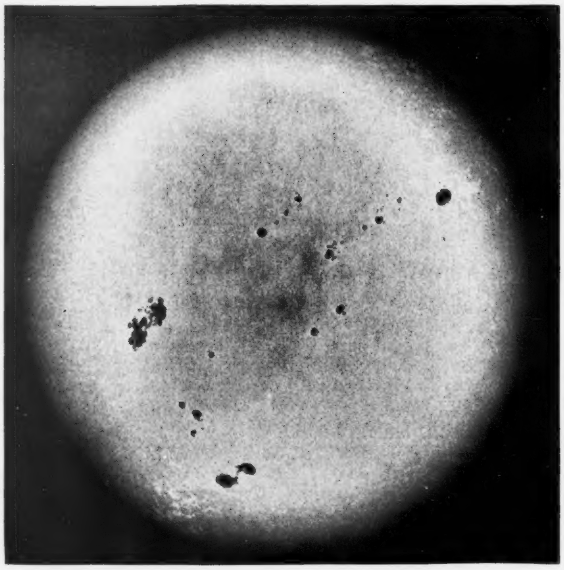
MARSHALL MELIN
Research Station for Satellite Observation
P. O. Box 4, Cambridge 38, Mass.

Auroral rays diverging from the observer's zenith form a corona during the display of September 3rd, photographed at Sandwich, Illinois, by Nicholas Liepins at 10:16 p.m. Central standard time. The exposure was one minute, at f/2 on Tri-X film. At bottom center the stars of Delphinus are bright, while Epsilon Cygni is in the upper right.

The Great Aurora of Early September

AMATEUR ASTRONOMERS from coast to coast witnessed a spectacular auroral storm on the night of September 3-4, 1959. Auroral activity on a much smaller scale was observed on the following nights, but these weaker displays ended by midnight.

Solar observers noted increased activity on the sun three days prior to the northern lights. Sunday, August 30th, Howard C. Colton, of Fairport, New York, obtained the accompanying photograph, which shows a large number of sunspots and faculae.



Pronounced activity on the sun, indicated by the number of sunspots and faculae, preceded the widespread auroral display. This picture was taken on August 30th by Howard C. Colton, using Kodak Autopositive film, at the prime focus of his 6-inch f/15 telescope.

The duration and intensity of the September aurora varied with the locality, the shortest displays being reported from central and western sections of the country. The most distant observer was Alan McClure, who had set up cameras on Mt. Pinos, about 75 miles northwest of Los Angeles, California, to photograph Comet Alcock 1959f. He saw auroral activity at 7:40 p.m. and 12:35 a.m. Pacific standard time.

A long and detailed log of the event, as it appeared from Eightyfour, Pennsylvania, was kept by 15-year-old David R. Kaiser, from 10:30 p.m. to 4:00 a.m. Eastern standard time. He first noted a large rayed arc, blue-green in color, stretching from the western to the eastern horizon. In shape it resembled a huge rainbow.

Changes came rapidly, according to Mr. Kaiser. At 10:40, a beautiful green

Compare this picture of the auroral corona with the one at the top of the page, taken 14 minutes earlier, both in Illinois. Elmhurst amateur James M. Hyer used an exposure of 25 seconds, at f/2.8 on Plus-X film. The stars of Delphinus can be identified near the bottom in this picture, too.

coronal aurora formed near the zenith, where pulsating rays from all four quadrants converged. Five minutes later, the corona dimmed and became whitish. In the west he saw a low glow, with a red ray rising from it 70 degrees up the sky. Northward, a rayed arc extended to the zenith, while in the south and west a short-lived ray bundle reached to 10 degrees of overhead.

The corona had vanished completely by 10:53, and all that remained was a rayed arc, covering the west, north, and east. This showed waves of light, traveling upward and from east to west. At exactly 11 o'clock this ceased, and a new rayed arc formed in the north, its western end doubled. Flaming aurora appeared in the east, varying from red to green, and pulsating in brightness.

As the Pennsylvania amateur continued his watch, he observed a sudden increase in auroral activity 12 minutes later, the rayed arc rising to an altitude of 75 degrees and changing to a brilliant red. At 11:20 a corona appeared nearly overhead, brightest on the north and with a gap on its southern side. This green corona disappeared five minutes later, leaving an arc in the north and west, from which rose a pulsating sheaf of rays. Still another brilliant green corona formed at 11:30 and grew larger. From it diverged red rays toward the four points of the compass. Ten minutes later this spectacular complex was nearly gone, the most conspicuous feature being a rayed arc in the northern sky.

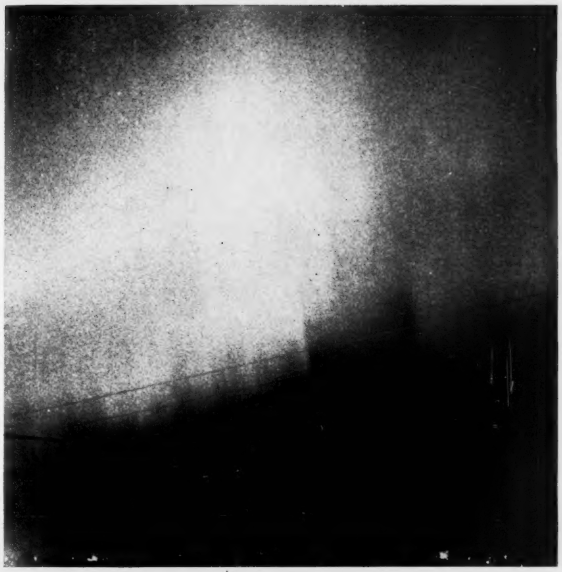
Thereafter auroral activity lessened. From 2 to 3:45 a.m., Mr. Kaiser saw only a glow in the north that shrank progressively until by 4 o'clock it was completely gone. But an hour earlier, in Pittsburgh, Pennsylvania, W. A. Feibelman had resumed observing the aurora after a rest of three hours, to find the whole northern sky lit up with waves and rays of intense green color. He finally lost the declining aurora in the dawn light.

The following amateurs also described the September display, including the distinctive coronal activity: L. E. Reinagel, Kenmore, N. Y.; D. Czarick, Pottstown, Pa.; R. R. Zappala, Cleveland, Ohio; J. Stamm, Jr., Akron, Ohio; J. M. Hyer, A. Stewart, F. Mraz, and J. A. Marshall, Elmhurst, Ill.; N. Liepins, Sandwich, Ill.; R. Spaulding, Royal Oak, Mich.; G. R. Peters, Detroit, Mich.; D. G. and R. J. Airhart, Toronto, Canada.

Other reports were submitted by A. Moehrke, Poughkeepsie, N. Y.; D. Della Pietra, E. Rochester, N. Y.; L. Rick, Lorain, Ohio; G. Hunter, Ann Arbor, Mich.; J. P. Hyde, Elkader, Iowa; P. Connor, Fremont, Nebr.; J. R. Otoupalik, Greeley, Colo.; H. W. Lang, St. Louis, Mo.; and P. Nash, Townsend, Mont.

On September 5th an aurora was seen by L. Mattersdorf at Chesterfield, N. H.; H. A. Luft, Oakland Gardens, N. Y.; and E. D. Alpert, New Bedford, Mass.

The display was noted for the variety of its forms. At Pittsburgh, W. A. Feibelman took these pictures that illustrate some main auroral types. The first, taken at 9:50 p.m. EST, shows a broad, homogeneous arc in the north. By 10:42, the arc had formed a rayed structure, as shown in the second picture. At 3:40 a.m., when the third photograph was made, the entire northern sky was bright with intensely green draperies. This was by far the brightest aurora of the year, rivaling the great display of February 10-11, 1958, according to Mr. Feibelman's report.



AMERICAN ASTRONOMERS REPORT

Here are highlights of some papers presented at the 103rd meeting of the American Astronomical Society at Toronto, Canada, Aug. 30-Sept. 2, 1959. Complete abstracts will appear in the Astronomical Journal.

Distance of the Sun

An extremely precise radio method of finding the sun's distance has been proposed by A. E. Lilley, Harvard Observatory, and Dirk Brouwer, Yale Observatory. It uses the same principle — Doppler shifts caused by the earth's motion around the sun — employed by an older optical technique involving observations of stellar spectra. When the earth moves toward a star, there is a shift of stellar spectrum lines toward shorter wave lengths, while for a receding earth the displacement is to longer wave lengths. In practice, the optical procedure did not give the accuracy that its radio counterpart now offers.

If a radio source is located behind a cloud of interstellar hydrogen, the 21-centimeter line of neutral hydrogen can be observed as a very sharp absorption feature. It is planned to measure the frequency of such an absorption line (for a source near the ecliptic) at different times of the year for several years. Because of the earth's revolution, the observed frequency of the absorption line will vary back and forth during the year. Thus it will be possible to ascertain the orbital velocity of the earth, and hence the precise size of its orbit and the distance to the sun.

Dr. Brouwer's computations show that the method should be capable of fixing the sun's distance to one part in 300,000 — a precision hitherto promised only by radar observations of Venus. The main limitation to the accuracy attainable is the rotation of the earth, which may change the observed frequency of the 21-cm. line by one cycle in the course of 20 seconds. This thus limits the time that can be profitably spent on any single measurement.

Actual observations will start early in 1960, at the Naval Research Laboratory and at the Agassiz station of Harvard Observatory. For recording the hydrogen line, a new radiometer has been developed, with financial support from the National Aeronautics and Space Administration.

The University of Toronto, where the American Astronomical Society met, operates this 74-inch reflector, which for 25 years has been Canada's largest telescope. It is housed in a dome 61 feet in diameter.

Moon's Distance by Radar

Hitherto, astronomers have relied upon triangulation for finding the distance from the earth to the moon, either by direct measurements of the moon's position in the sky as seen from widely separated observatories, or from times of occultations of stars. With either method, the moon's distance can be derived in terms of the earth's size, which is known rather precisely.

Preliminary results from a radically different approach — radar ranging — were reported by R. H. Bruton, K. J. Craig, and B. S. Yaplee, of the Naval Research Laboratory. During October and November, 1957, they measured the two-way travel times of 60,000 pulses of 10-centimeter radio waves reflected from the moon. Although the beam-width was 30 minutes of arc, at this wave length the moon reflects like a polished sphere, all of the echo coming from a very small area in the middle of its disk.

The NRL scientists found in this way that the average center-to-center distance to the moon is 238,855.95 miles, with an uncertainty of ± 0.75 mile. This is in close agreement with the results previously found by triangulation.

One unexpected difficulty is that the daily measurements showed a monthly variation of a large fraction of a mile, after all known effects had been allowed for. To investigate this phenomenon, a new seven-month series of observations is under way.

Pressure-Induced Nuclear Reactions in Stars

Astrophysicists have long been familiar with thermonuclear reactions in stellar interiors, processes whose rates depend mainly on high temperature rather than density. A. G. W. Cameron, of Atomic Energy of Canada, Ltd., now calls attention to a different behavior of nuclear reactions occurring in extremely condensed matter. Such processes are little affected by temperature, but their rates are very sensitive to density.

For them, Dr. Cameron has coined the term *pycnonuclear reactions,* from the

Greek *pyknos* (compact, dense). He has computed the rates for three important processes of this kind: the conversion of C^{12} to O^{16}, N^{14} to O^{18}, and O^{16} to Ne^{20}, a helium nucleus being added in each case.

One instance where processes of this sort may take place was described by Dr. Cameron. In a Population-II star of about the sun's mass, helium reactions can build up elements as massive as neon, but the latter needs a temperature of 1.2 billion degrees to enter into further thermonuclear phenomena. However, in such a star this temperature might not be reached, and after the helium burning stops the star's core would contract to extreme density, becoming degenerate.

At this stage pycnonuclear reactions would set in, the star expanding (possibly explosively as in a nova) because of the heat generated. The C^{12}-O^{16} reaction may be the principal ignition process initiating nova explosions. For stars at the tip of the red giant sequence in Population I, the N^{14}-O^{18} reaction is probably the cause of core expansion.

Color-Magnitude Diagram for Visual Binaries

In recent years, color-magnitude diagrams have been derived for numbers of galactic and globular star clusters. Two important uses of such diagrams are to indicate observationally the evolutionary development of stars, and to determine accurate absolute magnitudes for stars of high intrinsic luminosity. Because so few star clusters are suitable for this kind of study, Gustav A. Bakos, now of the Smithsonian Astrophysical Observatory, points out that visual binary stars can add valuable information.

According to current views of stellar evolution, if the two components of a binary star system differ in brightness by several magnitudes, in the great majority of cases the fainter component will be on the main sequence. Accordingly, the color of the fainter star tells its absolute magnitude. Then, if the magnitude difference between the components is measured, along with the color of the brighter star, its location in the color-magnitude diagram is also established.

Dr. Bakos proceeded to measure photoelectrically the apparent magnitudes and colors of both components of 75 binary systems, using for this purpose the 19-inch reflector of David Dunlap Observatory. He took spectra with the David Dunlap 74-inch reflector at a dispersion of 33 angstroms per millimeter, in order to determine the absolute magnitudes of the primary components. In this way he compiled the color-magnitude array shown here. The primary components, plotted as open circles, are either giants or main-sequence stars. With few exceptions, the fainter members are on the main sequence, as expected.

In this diagram, curves have been added to show the evolutionary tracks of stars in a number of galactic star clusters. The greater the age of a cluster, the lower is the branching-off point of its track upward from the main sequence. Also, the more massive a star, the faster it will evolve, and the farther it will have moved in the diagram from the zero-age main sequence.

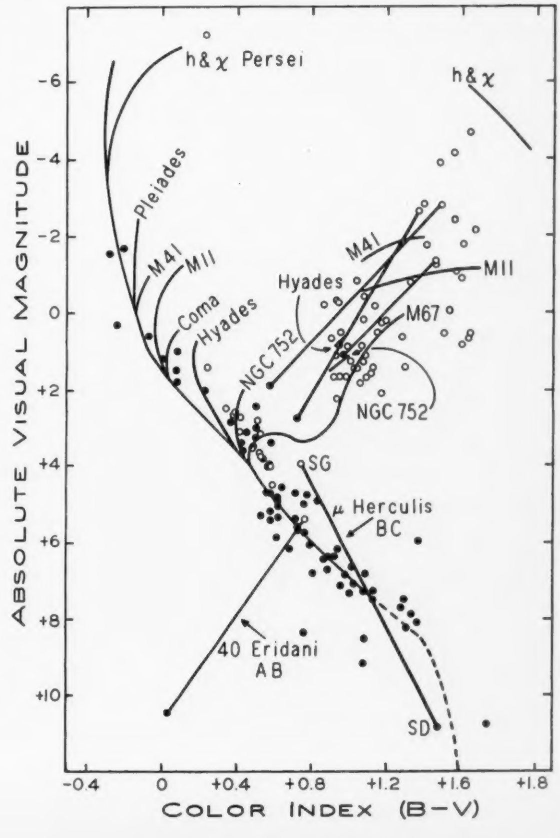
By matching the positions in the color-magnitude array of the components of a binary system with the track of a cluster, the approximate age of the binary can be found. Thus, a binary for which the plotted points agree with the pattern for NGC 752 should have about the same age, on the order of one billion years, as that cluster.

Of special interest are the double stars that lie in the same region of the diagram as the very old cluster M67, whose age is generally considered to be about five billion years. Those visual binaries whose brighter components lie to the right of the cluster track must be even older, about 10 billion years, according to Dr. Bakos' estimate. He points out that some recently observed galactic clusters have color-magnitude arrays indicating they, too, are older than M67.

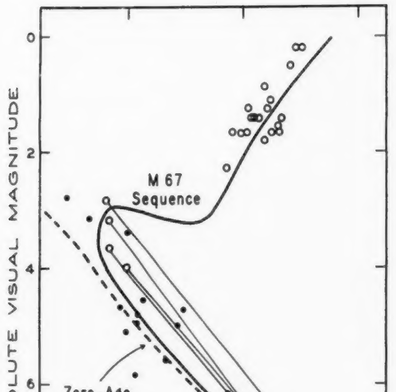
Polarization of Light of Moon and Planets

A difficult but important observational problem is the comparison of the properties of interplanetary particles with those in interstellar space. But the moon, Mars, and Venus are continually collecting interplanetary particles, which may be expected to produce polarization effects in reflected sunlight. At McDonald Observatory in Texas, the Indiana University astronomer Thomas Gehrels has begun a study of these solar system bodies, as well as of the nebula NGC 7023, which shines by starlight scattered by interstellar dust.

Dr. Gehrels' observations are made with a Wollaston photometer attached to the 82-inch reflector. In this device, light is separated by a Wollaston prism into two beams, plane polarized at right



Right: The colors and absolute visual magnitudes of visual binaries, determined by Gustav A. Bakos with the 19-inch and 74-inch telescopes of the David Dunlap Observatory. The thin lines connect primary and secondary stars in a few special cases. Superimposed on the chart are the observed sequences of important galactic clusters, their ages ranging from a few million years, for the Double Cluster in Perseus, to five billion years for M67 in Cancer.



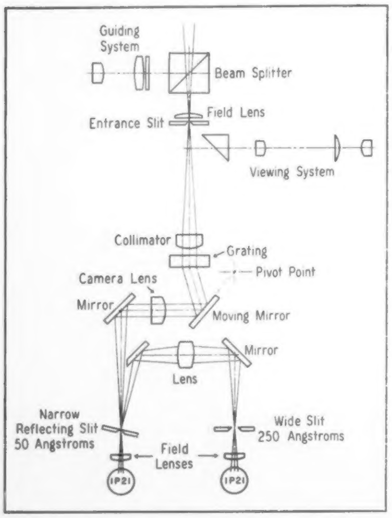
Left: Binaries with color-magnitude properties like those of stars in the cluster M67, indicating that they have similar evolutionary ages. Most of the primary stars lie on the giant branch, the secondaries on the main sequence of the cluster.

angles to each other, whose intensities are measured with photomultiplier tubes. A complete observation, requiring 30 minutes, consists of such measurements for six orientations of the prism, in ultraviolet, green, and infrared light. Because the two beams are recorded simultaneously, even during poor seeing or variable sky transparency the amount of polarization can be determined with an accuracy of about 0.1 per cent.

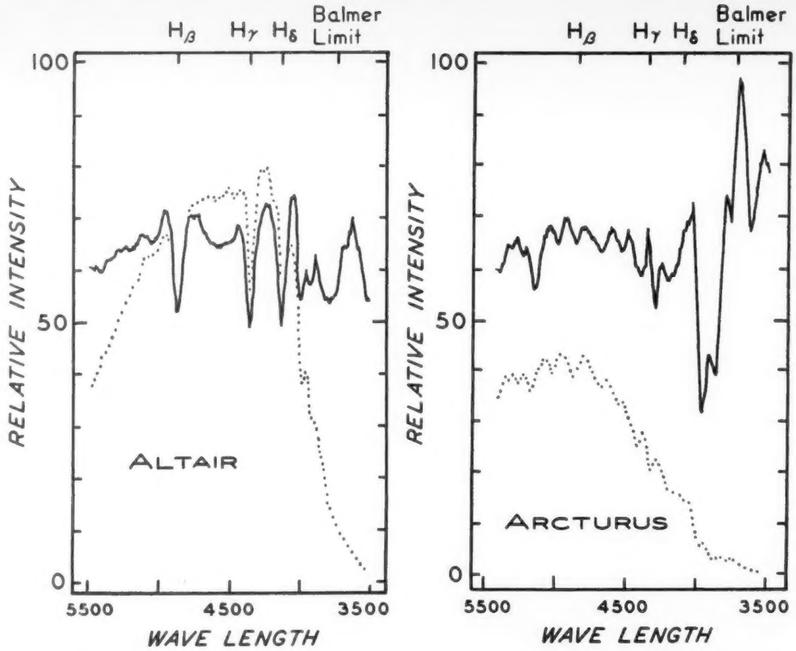
Seven small lunar regions, each about four miles in diameter, have been, observed in detail to determine how the polarization and brightness change with the moon's phase. The polarization is least in the infrared (10,330 angstroms) and greater in the green. In the ultraviolet, at 3250 angstroms, the polarization is strongest, and for lunar maria at quarter phase can amount to as much as 23 per cent. In this respect, the floor of the crater Plato behaves as the maria do. Dr. Gehrels' measurements in green light agree well with the earlier visual polarimetric observations by B. Lyot in France.

Mars and Venus show the same wave-length dependence as the moon, strongest polarization occurring in the ultraviolet. A peculiar result is that for Venus the ultraviolet plane of polarization differs by 90 degrees from that at longer wave lengths.

The marked ultraviolet effect indicates that light is being scattered by particles smaller than about 0.3 micron (1.2×10^{-5} inch) in diameter. In the case of Venus, two types of particles may be involved. Dr. Gehrels comments: "On Mars, and even on Venus, we may be observing accreted interplanetary particles suspended in the atmosphere." He suggests that they are of the same nature as micrometeorites in the terrestrial atmosphere.



In the Meinel ratio spectrometer, the narrow slit allows only a 50-angstrom band-width to pass to its photocell, but the slit jaws are polished to reflect the remaining spectrum to the second slit, which is wide enough for 250 angstroms to pass.



Ordinary spectrographic intensity tracings are dominated by the basic energy curves of the stars, as shown by the dotted lines in these charts of Altair, an A7-type star, and Arcturus, of type K2. The Meinel spectrometer compensates for the energy curve, however, giving the normalized solid-line tracings. Kitt Peak National Observatory charts.

As for the reflection nebula NGC 7023, parts of it were observed at wave lengths of 3700, 5700, and 8200 angstroms, where 13, 19, and 22 per cent polarization are typical values. These indicate interstellar particle sizes of a few microns. But in the case of eight individual stars, the infrared interstellar polarization was found to be appreciably less than at 6500 angstroms.

Ratio Spectrometer

A. B. Meinel, of Kitt Peak National Observatory, has invented a simple and effective device for charting automatically the light intensities of features in a stellar spectrum. The starlight collected by a telescope falls on a grating that forms a spectrum which is scanned simultaneously by two slits. One slit views a 50-angstrom width of the spectrum, the other a 250-angstrom band centered upon the first.

During scanning, the two slits remain fixed while light reaches them from a turning mirror. Behind each slit is a 1P21 photocell, and the *ratio* of the two photocurrents is traced by a pen recorder. Localized absorptions and emissions in the spectrum appear as dips and peaks, respectively, on the tracing.

Besides its speed and convenience, the ratio spectrometer has other important advantages. Because the spectrum is in effect being compared with itself, the intensity ratio is unaffected by fluctuations in sky transparency or seeing, or by guiding errors. Also, the general course of the tracing is more-or-less horizontal, making small features easier to recognize.

Dr. Meinel has built an experimental model of the device, using it with a 16-inch Cassegrainian reflector at Kitt Peak to observe 200 stars of spectral type G. It is possible to record stars as faint as the 5th magnitude, 10 minutes being required for a scan from about 3500 to 5500 angstroms.

The ratio spectrometer can be used for accurate spectral classification and for the determination of absolute magnitudes of stars. Dr. Meinel suggests that the device, when used with a very large telescope, may serve for measuring the red shifts of remote galaxies, by noting the wave-length change of the entire spectrum pattern with respect to the spectrometer's calibration scale.

DAYTIME AURORAS

For many years there has been controversy concerning the possibility that intense auroral displays may be visible in full daylight. Until recently, the only report that had gained general acceptance was an observation in New Zealand, in May, 1921. Cicely M. Botley has now collected 15 probable cases of daylight auroras between the years 1744 and 1958.

From her list, published in the August *Journal* of the British Astronomical Association, she concludes that the phenomenon is by no means as rare as has been thought. "It therefore seems that aurora, at any rate in the great class, is not confined to the night hemisphere but is global in the most literal sense, a conclusion also supported by radar."

NEWS NOTES

UNIVERSITY GIVES OBSERVATORY TO AMATEUR ASTRONOMER

When Miami University, at Oxford, Ohio, recently decided to dismantle its observatory, the 12-inch Clark refracting telescope was presented to Leslie C. Peltier, of Delphos, Ohio. One of the nation's most famous amateurs, Mr. Peltier has discovered a dozen comets since 1925, and has been a very active variable star observer. Most of his work has been done with a 6-inch refractor lent to him by Princeton Observatory.

The 12-inch f/15.7 objective was made by Alvan Clark and Sons in 1868. For many years the telescope was used at the observatory of Wesleyan University, Middletown, Connecticut, and was transferred to Miami in 1925. The gift to Mr. Peltier also included the observatory building with its 22-foot dome, a 3-inch Gaertner transit instrument, and a sidereal clock.

Already moved by truck to Delphos, the building and telescope are being reerected exactly as they were at Miami University, on Mr. Peltier's property about 100 yards north of his residence. The location is at the west end of the town, with no detrimental lights or smoke. The 12-inch is expected to be in active use by the end of the year, for observations of faint variable stars.

VELOCITY OF LIGHT

There is a curious discordance among modern experimental determinations of the velocity of light, for measurements made with visible light give slightly smaller speeds than do those with radio microwaves. R. A. Miller and A. Lopez, Manila Observatory, suggest that this difference arises from the time taken by reflection from mirror surfaces used in the optical methods. The work done with standing microwaves in resonant cavities should be essentially free of such an effect.

In support of their conjecture, the Philippine scientists call attention to the optical determination by L. E. Bergstrand a decade ago. This used only a single mirror reflection and gave a velocity of 299,792 kilometers per second — very close to the results of microwave experiments.

On the other hand, in the optical determinations made by A. A. Michelson and others up to 1935, light beams were sent back and forth over long paths by means of multiple reflections from rapidly rotating mirrors. Thus F. G. Pease and F. Pearson used 13 reflections between points more than 10 miles apart, finding a velocity 18 kilometers per second less than Bergstrand's.

Drs. Miller and Lopez have made a first attempt to calculate the delay suffered by visible light during reflection from silver, finding roughly 1.7×10^{-10} second. This lag is of about the right size to account for the differences between the early optical and the recent microwave work, they report in the September *Journal* of the Optical Society of America.

CATALOGUE OF DWARF GALAXIES

Sidney van den Bergh, of David Dunlap Observatory, has used National Geographic-Palomar Sky Survey prints to compile a catalogue of 222 dwarf galaxies, characterized by very low intrinsic luminosities. Faint objects were included in his list if they met two criteria: low surface brightness, and little or no central condensation on the photographs taken in red light.

Four different types of such galaxies are distinguished by Dr. van den Bergh. *Dwarf irregulars* resemble NGC 6822 in the local group of galaxies. *Dwarf spirals* exist in two varieties, either as a short bright bar on a fainter background, or with resolved stars and nebulosity in elongated patches resembling segments of a spiral arm. *Dwarf spheroidal* systems, of very low surface brightness, are rather easy to identify at large distances, but more difficult to recognize if they are near enough to be completely resolved into stars. IC 3475 in the Virgo cluster is the brightest known representative. Lastly, there are *dwarf ellipticals,* but they are difficult to distinguish from their giant counterparts, and Dr. van den Bergh's list contains very few.

Of the 22 known probable members of the local group of galaxies, no fewer than 17 are dwarf systems. A dozen were included in Dr. van den Bergh's survey, which is published as Vol. 2, No. 5, of the *Publications* of David Dunlap Observatory.

GUSTAV LAND DIES

American astronomy lost a major link with the German tradition of celestial mechanics and refined positional measurements when Gustav Land of Yale Observatory died on September 26th.

Born at Danzig on April 15, 1880, as Gustav Deutschland, he studied at Berlin University, where his thesis was an investigation of the motion of a comet during a very close approach to Jupiter. Afterward he was at Leipzig Observatory, and became well known as an expert in stellar statistics.

In 1939, Dr. Land left his native country, and, after working for a short time with the British Nautical Almanac Office, came to the United States as a staff member of Sproul Observatory. He was appointed research assistant at Yale in 1941, a position he held until his death.

While in America, his chief study concerned the measurement of star positions on photographic plates, and methods for pushing the accuracy of this work as far as possible. Particularly noteworthy were his studies of errors caused by emulsion shifts, and of practical ways of overcoming them. Dr. Land published in the Yale Observatory *Transactions* a searching analysis of the accuracy of the Yale measurements of trigonometric parallaxes of stars. The conclusions he reached in this memoir are of basic importance to improving our knowledge of stellar distances.

IN THE CURRENT JOURNALS

OCCURRENCE OF LIFE IN THE UNIVERSE, by Su-Shu Huang, *American Scientist*, September, 1959. "Granted that all kinds of stars have an equal chance of possessing planets, we ask: Is there any way of knowing which kinds of stars favor the existence of life on their planets? This question can be reasonably answered, we find, with our present knowledge."

METEOR TRAILS USED IN RADIO COMMUNICATION

In recent years, the overcrowding of the high-frequency bands normally employed for long-range radio communications has stimulated varied attempts to utilize wave lengths so short that ordinarily they would serve only over a line-of-sight path. The National Bureau of Standards now reports successful development of a two-way message transmission system, in which 49-megacycle signals are reflected from the ionized trails left by meteors.

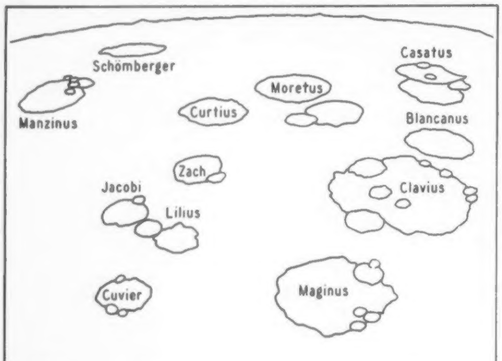
The message to be sent is first recorded on magnetic tape. With both transmitters on the air, the presence of a suitably located meteor trail is detected within a few thousandths of a second. Then the message is sent, most satisfactorily at 2,400 words per minute — 40 times the speed of present teletype transmission. When the signal strength falls too low, as the meteor trail dissipates, the transmission is halted temporarily.

Extensive tests made over an 800-mile path shows the method can compete effectively with other long-range systems, and is relatively free from ionospheric disturbances. However, the simultaneous occurrence of two meteors can cause garbled signals.

In a project known as Janet, Canadian scientists had previously used meteor ionization to aid short-wave radio communications (SKY AND TELESCOPE, October, 1956, page 541).

INTERNATIONAL ASTRONOMICAL UNION 1961 MEETING

The 11th general assembly of the International Astronomical Union will be at the University of California in Berkeley during August, 1961. More than 1,000 astronomers from all parts of the world are expected to attend. IAU meetings are held every three years, the latest having been at Moscow in 1958.



The southern part of the moon, as represented on one sheet of Philipp Fauth's great lunar map, left incomplete when he died in 1941 and now being prepared for publication by his son, Hermann Fauth. The original is on a scale of one to a million, corresponding to 11½ feet for the moon's diameter. This reproduction is on a scale only 29 per cent as great. The small key chart, left, identifies several of the more prominent craters, including Clavius, 144 miles in diameter; Tycho, 54; and Moretus, with its massive central peak, 73 miles. Fauth uses contour lines to indicate vertical relief, a change from the hachures in his earliest charts. These contours are careful estimates rather than the result of detailed measurements. Possibly never again will a lone selenographer prepare so elaborate a map of the whole moon entirely from his own visual observations. The multitude of smaller formations visible in very large telescopes is so great that future visual charting will probably be co-operative, insofar as it is not superseded by photography or actual exploration. To appreciate the amount of detail in Fauth's map, and to judge its accuracy, the reader should compare the view in his own telescope with the depiction of, say, the crater Clavius.

All illustrations with this article are courtesy Hermann Fauth.

PHILIPP FAUTH and the Moon

HERMANN FAUTH

Philipp Fauth was 63 when this picture was taken in the summer of 1930. At that time, the German amateur was resuming lunar observations with a $15\frac{1}{2}$-inch refractor at his fourth observatory (pictured on page 23), at Grünwald, in Bavaria.

ANYONE who writes about the history of selenography should no more omit the name of Fauth than those of Mädler and Schmidt. Fauth was a leader in lunar studies and the author of maps and publications showing his unprecedented knowledge of the moon's surface. Although this amateur was world-famed among astronomers during his lifetime, recent books either fail to mention him or give him only a few inadequate words. In America he has remained almost unknown.

Philipp Johann Heinrich Fauth was born on March 19, 1867, at Bad Dürkheim in the German Rhineland, the oldest of three children in a long-established family of pottery makers. From his father he acquired outstanding artistic talents, that later showed themselves in unsurpassed lunar maps, and a lifelong love for music. Tending the pottery kiln at night, the father would fetch his youngster out of bed and carry him outdoors, wrapped in a blanket, to show him the beauty of the stars and the sun rising over the vineyards of the Rhine Valley. Coggia's comet in April, 1874, made a deep impression on the boy.

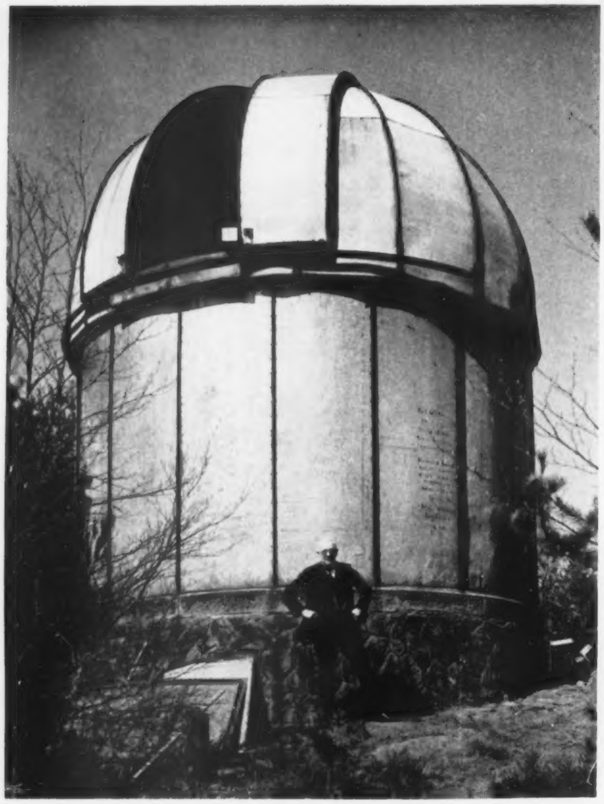
At secondary school in Kaiserslautern, Fauth began an enthusiastic study of astronomy. In 1885 he started observing the sun and moon with a small 18-power telescope, and two years later acquired his first really serviceable instrument, a 3-inch refractor. His two aims were to become acquainted with everything to be seen in the sky, and to draw what he saw better than the usual pictures in books. (At that time astronomical photography was a little-known novelty.) The boy's inspiration came from books, for he had not yet visited an observatory or met an astronomer.

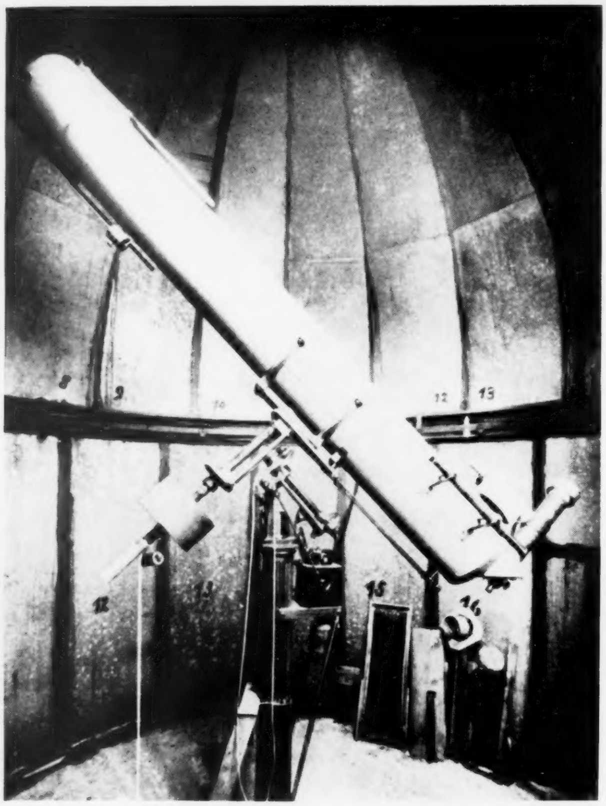
Fauth's first observatory, in use from 1889 to 1895, was located on the Lämmchesberg, near Kaiserslautern. Here, with a 6-inch refractor, he made the observations on which was based his atlas of 25 lunar regions.

In 1890, when Fauth became a school teacher, he built his first observatory in the southern part of Kaiserslautern, equipping it with a 6-inch Pauly refractor. At that time the west German observatories of Karlsruhe, Heidelberg, and Cologne had nothing larger. He devoted himself at once to the moon, Jupiter, and the nebulae. But two years later, the school board transferred him to the remote town of Oberarnbach in the western Rhineland, for it was taken amiss that a young teacher should have such a good city post.

Now his observing had to be done long-distance, each working night requiring a three-mile walk over a hilly road, then a 10-mile train trip, and another half mile on foot to the observatory – and back again in the morning. He kept this up for four years, in addition to his regular school duties. Fauth recollected: "During those years I won my spurs as an astronomer. In the summers I more than once saw the sun set as I began to observe, and rise as I closed up the observatory. In winter I needed all my enthusiasm. Deep snow and bitter cold were obstacles, but steady seeing and a transparent sky encouraged me to persist; the unforgettable impressions even during winter nights are among my fondest observing memories."

The fruits of these strenuous years



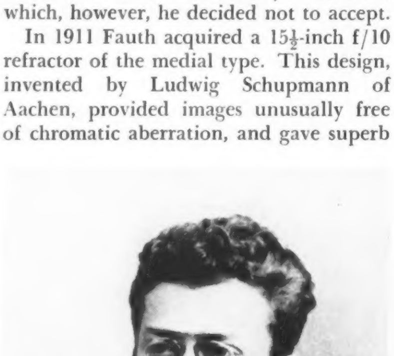


The third observatory that Fauth built, in use from 1911 to 1923, was on the Kirchberg near Landstuhl, in western Germany. At the left, Professor Fauth stands before the building. The interior view shows the 15½-inch medial refractor, an instrument of exceptional optical quality, which gave practically complete color correction. With this telescope the German amateur did much of his finest work.

were Fauth's first two memoirs, published in 1893 and 1895: *Astronomical Observations and Results in the Years 1890 and 1891,* and a similar report for 1893 and 1894. The latter included a topographic atlas of 25 lunar regions. Articles by him appeared in journals such as the *Astronomische Nachrichten* and *Sirius,* and he was already corresponding actively with fellow observers, especially Hermann Klein in Cologne, J. N. Krieger in Gern, Viktor Nielsen in Copenhagen, and Max Wolf in Heidelberg.

Fauth's success gained him the support of the Prussian Academy of Sciences for the construction of a more serviceable observatory in a better location. In 1895 he obtained a transfer to the school at neighboring Landstuhl, and near there on the Kirchberg he erected his second observatory, a dome-topped stone tower 26 feet high. It looked out over the treetops 450 feet above the town and 1,300 feet above sea level. Here Fauth obtained a wealth of observational results, and by 1902 had discovered some 5,600 new lunar craterlets and clefts. He was now established as a lunar specialist. In 1906, Wilhelm Foerster of Berlin encouraged him to write his first book, which also appeared in English translation as *The Moon in Modern Astronomy,* London, 1907. Professor Foerster furthermore recommended him for the post of assistant at a new observatory in Mexico, which, however, he decided not to accept.

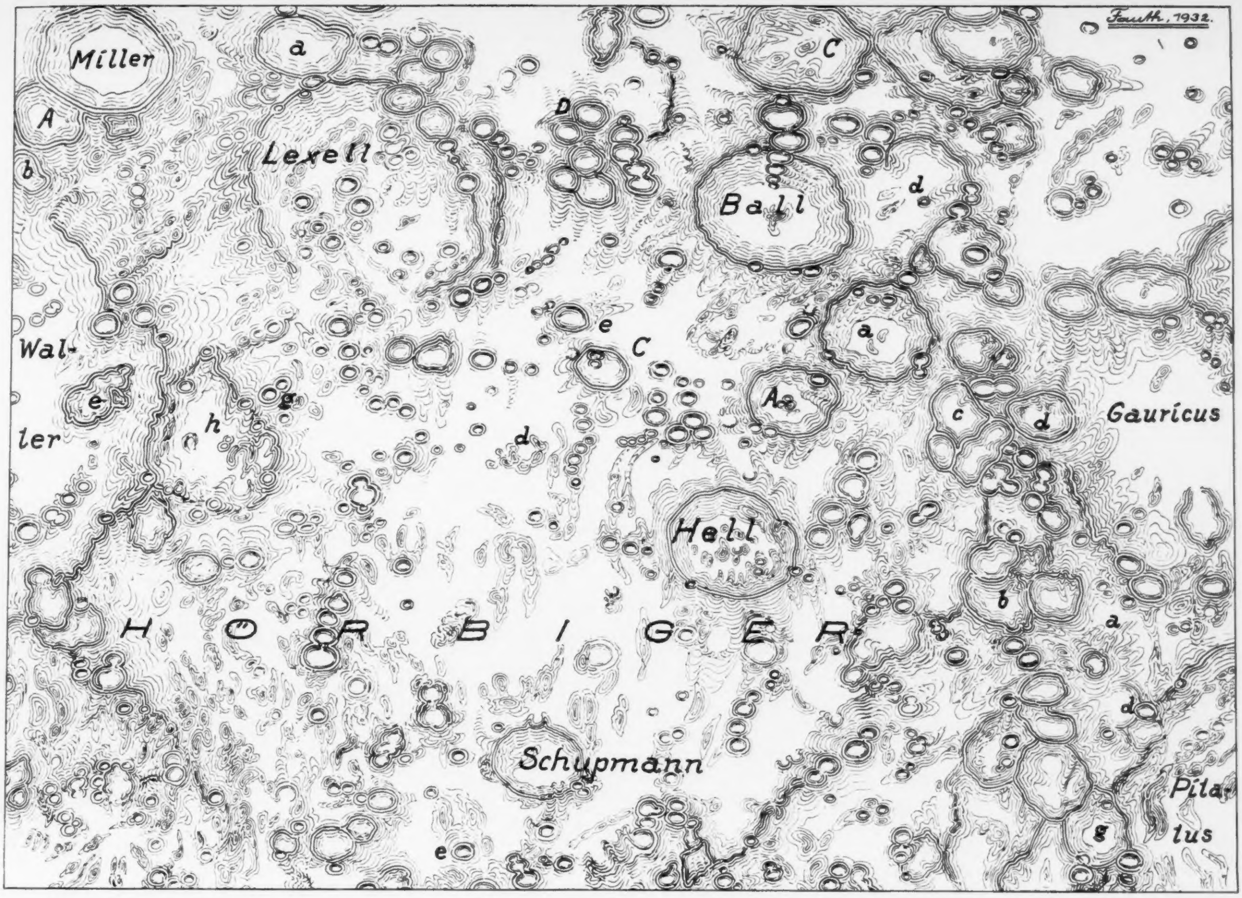
In 1911 Fauth acquired a 15½-inch f/10 refractor of the medial type. This design, invented by Ludwig Schupmann of Aachen, provided images unusually free of chromatic aberration, and gave superb performance. The third observatory, built for this telescope, stood 600 feet south of the stone tower. To the low sheet-zinc dome in a grove of young pine trees, Fauth welcomed thousands of visitors in the following years.



This photograph, taken in 1890, shows the young schoolteacher at the outset of his career as a lunar specialist.

His 28 years of activity at Landstuhl furnished the basis for many memoirs and books: in 1898, *Observations of the Planets Jupiter and Mars at Their Oppositions of 1896-97,* with 147 drawings and five maps; in 1912, a 790-page work, *Hörbiger's Glacial Cosmogony;* and in 1916, his *25 Years of Planetary Investigation,* with 245 illustrations. There were also innumerable lunar drawings, thousands of sunspot sketches, and an analysis of almost 3,000 fine drawings of Jupiter. Moreover, he wrote numerous astronomical articles and kept up an extensive scientific correspondence.

This intense activity was interrupted in 1923, when Fauth left the Rhineland because of the French occupation, and he became a teacher in Munich. He could not bring his medial to Bavaria until 1930, when he set it up near the town of Grünwald, nine miles south of Munich. There he continued his work, publishing at the age of 70 a large collection of drawings of formations very near the edge of the moon, observed at times of especially favorable libration. Three years later he was planning to move his observatory

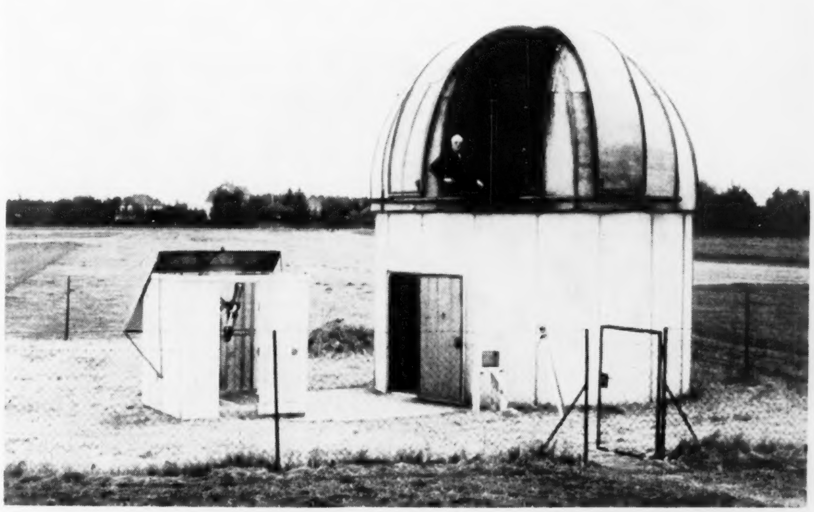


One of the 16 large-scale charts of Fauth's 1932 regional atlas shows the Hell Plain, in the south-central portion of the moon. The ruined and incomplete remains of an enormous crater, this plain has never been officially named, but Fauth designated it Hörbiger. About two inches left of the crater Hell on this chart is Cassini's bright spot, one of the most brilliant lunar areas at full-moon phase. The low-walled crater labeled Schupmann is generally known as Hell B.

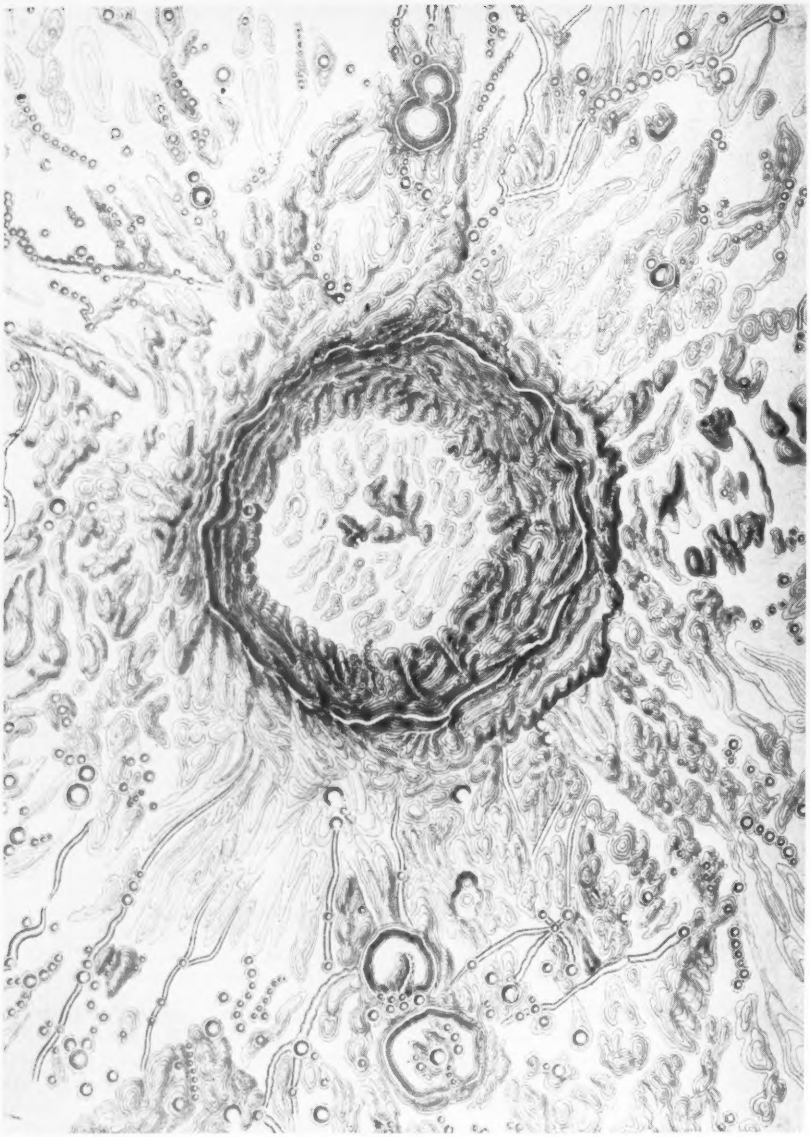
to Rauhe Alb in Swabia, when he died on January 4, 1941. Philipp Fauth's last contribution was a yet-unpublished work of advice and suggestions for future lunar observers.

Today the sites of Fauth's four observatories have been absorbed by the growth of cities, and his famous medial telescope disappeared at the end of World War II. There remain only his dwelling and his grave in Landstuhl, and streets named for him in Bad Dürkheim, Landstuhl, and Grünwald. His main legacies are his great selenographical works: the comprehensive 600-page treatise of 1936, *Our Moon;* his lunar atlases of 1895 and 1932; and his great lunar map, $11\frac{1}{2}$ feet in diameter and on a scale of 1:1,000,000. The 22 sheets of this map survived World War II, but Fauth had lived only long enough to make the finished drawings for five of them. As his son, I have undertaken to complete the careful pencil drafts of the remaining 17 sections. The long-awaited publication of this map will probably be within a year. From the sample section reproduced on page 20, the reader may gather some impression of the remarkable detail and realism of Fauth's representation of the moon.

This map has had a long history. Over the years Fauth spent thousands of hours at the telescope, making the drawings that in 1936 he began to combine into a general map. Already in 1932 he had prepared a lunar atlas of 16 regional charts, the labor of a period when convalescence from a severe illness interrupted his observing. These 16 charts were beautiful depictions on a large scale of areas such as Eratosthenes, Taruntius, Plinius, Ptole-



Fauth's fourth observatory, at Grünwald, which he used from 1930 until his death in 1941. He is here sitting on the edge of the dome slit, and the medial can be seen inside. The hut at the left contains a small telescope for sunspot counts.



This map of the large crater Copernicus was prepared by Fauth in July, 1932, from observations with his 15½-inch refractor. The original scale is 1:200,000, the contour lines indicating 200-meter intervals in elevation. At top center is a conspicuous double crater, the larger being Fauth, the smaller Fauth A. Nearest the bottom edge is the crater Gay Lussac. Copernicus itself is remarkable for its intricate interior terraces, the inner wall descending in a series of irregular steps.

maeus, and Posidonius, as well as the Hell Plain, and the double crater Fauth (officially named after him). The great formation Copernicus is shown as it would be seen from directly above, without foreshortening, on a scale of 1:200,000.

The work on the 11½-foot map was delayed by Fauth's continual desire to add new details from additional observations. In 1939 he wrote, "I am constantly finding peculiarities that lend fresh interest to the work. In a way, all lunar maps are premature, for the detail is truly inexhaustible."

This cautious and responsible attitude helps explain Fauth's deep skepticism of reports of lunar change. In an important article (*Astronomische Rundschau, 3,* 172-176, 1901), he marshaled strong arguments that no alteration had actually occurred in the famous case of the object Linné, in Mare Serenitatis, and he again presented his proofs in his 1936 book. Yet others ignored his demonstration that Schmidt was mistaken in believing that Linné had altered from a crater to a bright patch.

"Without this error," he wrote, "lunar literature would be free from many of its fantasies; as it is, proofs of 'changes' on the moon spring up like weeds. We witness over and over again how 'scientific' methods and time and effort are squandered on unprofitable problems." Although Fauth was widely recognized as the leading lunar expert of his day, his warning went unheeded.

The German selenographer was deeply disappointed that for decades he had been publishing fine drawings of the moon without finding fellow workers whom he regarded as of his own caliber. "Either they were content with the success of lunar photography, or they shied away from creative work at the eyepiece, which demands patience and skill. Instead, the enthusiasm of students of the moon has been for selenological problems, and they have advanced wild theories without coming to grips with hard facts. Lunar work has not achieved the high level that should have been stimulated by the publication of Schmidt's lunar atlas of 1878."

Philipp Fauth's extensive contributions to lunar studies were nevertheless only one aspect of a versatile career. At the same time, he was a widely known educator and a highly accomplished musician. The biography that I am now writing should furnish a clear and faithful image of him.

QUESTIONS... FROM THE S+T MAILBAG

Q. How many natural satellites in the solar system can be seen with a 3-inch telescope?

A. About eight. These are the earth's moon, the four Galilean satellites of Jupiter, and three of Saturn's moons – Rhea, Titan, and perhaps Iapetus.

Q. Have any features on the invisible side of the moon been tentatively mapped?

A. Yes. Certain bright rays reach around the moon's edge into the visible hemisphere. On the assumption that these rays, like those of Tycho and Copernicus, diverge from craters, the locations of several craters have been derived on the far side of the moon.

Q. What does the symbol Δ mean when used with a number to label objects on a star chart?

A. These are southern clusters and nebulae in the catalogue of James Dunlop, who observed in Australia about 1825. Dunlop numbers are seldom used, as his list was superseded within a few years by John Herschel's catalogue.

Q. Which astronomical constants have been most precisely determined from observation?

A. The orbital periods of the earth and the moon, in terms of the length of the day.

Q. Who invented the telescope?

A. This question has never been fully settled. Apparently it was independently invented by several people at the beginning of the 17th century, among them Hans Lippershey, to whom credit is usually given. W. E. S.

Getting Acquainted with Astronomy

Techniques of Lunar and Planetary Observing — II

After the beginner has gained some acquaintance with the moon and planets, his growing experience is likely to suggest some specific observing programs, such as were described in the September issue. Whether his purpose is private enjoyment or adding to astronomical knowledge, the following hints should be helpful.

It is desirable to get in touch with other amateurs having similar interests, preferably by joining one or more of the major observing societies. The director of the Association of Lunar and Planetary Observers is Walter H. Haas, Pan American College Observatory, Edinburg, Tex. For information about the British Astronomical Association, write to the Assistant Secretary, 303 Bath Rd., Hounslow West, Middlesex, England. A new organization devoted to observations of the moon is the International Lunar Society, whose permanent secretary is A. Paluzie-Borrell, Diputacion 377, Barcelona, Spain. All three of these groups publish journals in which amateurs report their work. In addition, your local amateur society may have active observing sections.

An excellent habit for the observer is keeping a notebook in which every observation is written down at the time it is made, regardless of whether it seems important or not. Trust nothing to memory; a valuable discovery can be lost because the details were not written down when their recollection was fresh. Records should never be changed afterward. One convenient system is to keep the original in pencil and to make later additions in ink.

The practiced observer habitually records the time of observation for each entry in his notebook. On the moon, the advance of the sunrise or sunset line is so rapid that the appearance of details near it can change within a few minutes. The planets Mars, Jupiter, and Saturn can change their aspects rapidly as they rotate, so the exact moment of an observation must often be known for its proper interpretation.

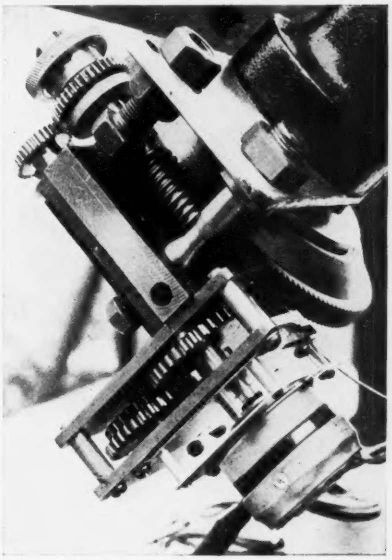
In addition, notes should be made of the sky conditions at the time. We observe from the bottom of a deep ocean of turbulent air, which bends light rays irregularly as they pass through it. Consequently, stars are seen by the unaided eye to twinkle, and telescopic images vibrate and lose their sharpness. At the same time, there may be dimming by clouds, smoke, or dust. A careful distinction is drawn between *seeing,* which indicates the steadiness of the atmosphere, and *transparency,* which indicates its ability to transmit light.

It is customary to record the seeing on a scale of 0 (worst) to 10 (best). Similarly, sky transparency is often described on a scale of 0 (nothing visible) to 5 (very clear). The subject of seeing is discussed further on page 37 of this issue.

One reference work that is invaluable to the serious lunar or planetary student is the *American Ephemeris,* in particular the section containing the ephemerides for physical observations of the moon and planets. It gives complete information about conditions of solar illumination and the orientation of their surfaces with respect to the earth. Simplified compilations of such data are given in the annual *Handbook* of the British Astronomical Association, and in the *Observer's Handbook* of the Royal Astronomical Society of Canada.

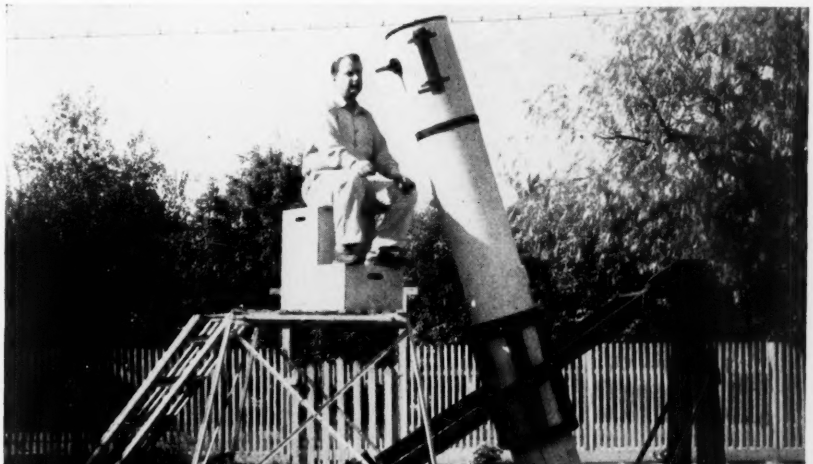
Anything that adds to the comfort and convenience of the observer will increase the amount of work he can do in an evening. If the telescope does not already have a clock drive, adding one should be seriously considered. With a driveless instrument, objects drift rapidly out of the field of view, especially when high powers are used, and the frequent resetting of the telescope is a nuisance. Moreover, brief intervals of fine seeing can be missed because the observer's scrutiny has been interrupted.

Many amateurs have built their own drives at low cost. The first two volumes of *Amateur Telescope Making* contain many descriptions and pictures of homemade drives. Edgar Everhart discussed gear ratios for sidereal and other drive rates in Sky and Telescope for August, 1957, page 494 (out of print). Of course, many commercial models are available. Setting circles are less necessary for the planetary observer, who would need them only for locating Uranus or Neptune, or for observing the brighter planets by day.



An electric drive for a 10-inch telescope, made by the late J. H. Pruett.

The eyepiece of a long-focus Newtonian reflector can sometimes be awkwardly high above the ground, unless there is a suitable support or short sturdy stepladder available. There should be a convenient place close at hand for the observer's notebook, sharpened pencils, and charts. One accessory that can be strongly recommended is a box with a top of heavy ground glass, perhaps one foot square, and containing an electric light. With such an arrangement, drawing paper can be illuminated from below, making sketching the moon or planets much easier.



Several years ago, Thomas R. Cave, Jr., Long Beach, California, designed this observing platform and stand for his clock-driven $12\frac{1}{2}$-inch f/9.7 reflector.

Radio Astronomy Receivers—I

FRANK D. DRAKE, *National Radio Astronomy Observatory*

AT FIRST SIGHT, the task performed by a radio telescope is incredible. The total power falling on the entire surface of the earth from the brightest radio source other than the sun, Cassiopeia A, is about 100 watts – just enough to operate a single light bulb of that rating. From this supply, a giant radio telescope will collect only about 10^{-14} watt.

The total radio power striking our earth in the famous 21-centimeter line of neutral hydrogen is scarcely 20 watts. Here a large radio telescope, receiving only a small fraction of the narrow band of available frequencies, may gather 10^{-17} watt. The faintest detectable radio sources provide our planet with but 1/100 watt of total power. Yet we can still manage to detect the millionth of a millionth of a millionth of a watt that is one telescope's share of this supply.

At the present time spectacular radio telescopes are springing up all over the world, especially in the United States. In each telescope, buried almost invisibly in the vast structure of the antenna, is a special radio receiver, usually called a *radiometer,* which detects and measures the radio energy collected by the antenna.

It is true that the resolving power is determined completely by the size and quality of the antenna, and these depend mainly on the money available to build it. But the faintness of detectable signals and the precision of radio intensity measures are largely controlled by the quality of the radiometer, and this depends chiefly on the ingenuity, knowledge, experience, and skill of the builder. For this reason, the design and construction of radiometers have appealed to some of the most nimble minds, who have brought to the field great vitality and fascinating advances.

Not only are the celestial signals weak, but they have no distinguishing features. Except for the 21-cm. sources, the radiation is at all frequencies, and the intensity of a particular frequency does not change with time, except in the case of solar system bodies. The radiation has the characteristics of random noise, just like static in a radio set. There are no dots and dashes, or tones, to tell us when we have found a signal. Furthermore, presently available receivers create far more noise power within themselves than is collected by the antenna. The problem facing the designer is to separate accurately the very faint celestial noise from that of the receiver, which is identical in nature but vastly stronger.

As a rule, the heart of the radiometer is a conventional receiver with all the usual tubes, coils, resistors, and other parts. To this is added electronic circuitry to increase stability and to distinguish signal noise from receiver noise. The conventional receiver performs the basic functions of all radios: It selects a certain band of frequencies, amplifies the power in that band, detects the amplified power, and presents the results in a convenient form.

The receiver design most frequently employed is the superheterodyne circuit, used in all home radios and TV sets, the incoming signal being mixed in a tube or crystal with a signal of nearly equal frequency generated internally. The two signals "beat," as in an out-of-tune piano, and the beat frequency, which now carries the signal information, is extracted, amplified, and detected. The advantage of this circuit is that the extracted beat frequency is much lower than the original signal frequency, and is more easily and cheaply amplified.

Until recently, the receiver output was universally recorded in graphical form by means of a moving-chart pen recorder. Lately, equipment has become commercially available that allows the output to be presented in digital form – as printed numbers or punched on tape in the proper code for direct insertion into an electronic computer. This latter method is rapidly gaining favor, as it eliminates the tedious work of measuring the pen recordings, avoids human error in data reduction, and enables the process to be carried out automatically by high-speed computers.

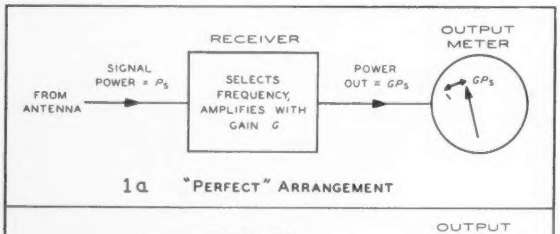


Fig. 1. The operation of an ideal radiometer, in which there would be no internal receiver noise, is compared with the situation in actual practice, where the output is a combination of external signal and internal noise.

Among the various complete radiometer systems, the most straightforward and obvious arrangement to extract signal from receiver noise is the *direct* or *total-power* radiometer. If a receiver is made extremely stable, the output power due to its noise will be nearly constant. When a radio source enters the antenna beam, there is a slight increase in output power, and this increase is a measure of the source intensity. This situation is shown in Fig. 1b.

In the direct radiometer a battery is used to provide a voltage equal to that of the receiver noise. These two voltages are applied to a circuit whose output is their difference. This differencing circuit thus acts to subtract out the receiver noise power, leaving only the increases in receiver output due to the presence of celestial radiation, as shown in Fig. 2a.

The proper performance of the direct radiometer depends entirely on high receiver stability. Because the receiver noise is being amplified, changes in the amplification, or gain, will cause fluctuations simulating changes in the input signal power. Since the receiver noise may be 10,000 times greater than the signal noise, it is necessary to have the gain vary by no more than one part in 10,000. Then the output fluctuations due to receiver gain variations will be less than changes due to the coming and going of celestial signals.

This is a very difficult standard to meet, and is a far cry from the one part in two or three that is acceptable in a radio or TV set. It is necessary to employ extremely stable electrical power supplies in radio astronomy receivers, particularly in the units that feed the tube filaments. Since slight variations in temperature affect gain, all receiver components in a direct radiometer are kept in rooms or containers that are held at very nearly constant temperatures, usually by means of heat pumps, air conditioners, or heaters controlled by sensitive thermostats. All this is costly, but provides the advantage of simplicity in the radio circuitry.

A variation of the direct radiometer, the *d.c.-comparison* type, is often used in 21-cm. work. Two separate bands of

frequencies are amplified by the receiver, separated, and detected individually. They are then put through the differencing circuit of a direct radiometer, one band replacing the battery. Since receiver noise and any wide-band cosmic noise are present equally in both channels, these are eliminated by the differencing circuit. However, if the receiver is tuned so that one band covers the 21-cm. line, the 21-cm. power will be in that band but not in the other. The output will then represent only the 21-cm. radiation being collected by the antenna.

A second, more sophisticated technique for overcoming receiver noise is the one used in the *switched* or *Dicke* radiometer (Fig. 2b), named after R. H. Dicke, who invented the method in 1946. The essence of this technique is to place a switch in front of the receiver, for alternate connection with the antenna and with a resistor. The signal power then comes to the receiver in pulses whose frequency and duration are controlled by the switch-frequency generator. Since the receiver is located after the switch in the circuit, the receiver noise does not have a pulsed character. The pulsing has, in effect, put a "tag" on the signal to distinguish it from the receiver noise.

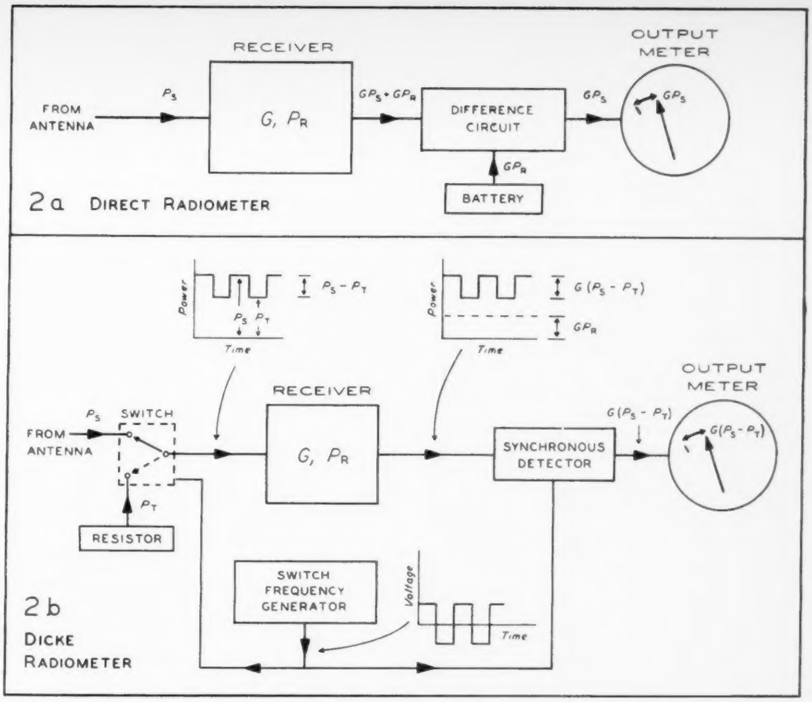


Fig. 2. Principles of direct and Dicke radiometers, explained in the text.

Hence, if we put a device at the receiver output which recognizes only power with the proper tag on it, we may eliminate the receiver noise. Such a device is called a *synchronous detector*. It is connected to the switch-frequency generator, and detects only signals that are synchronized in time and duration with the switch. Its output is a direct-current voltage proportional to the amplitude of the pulsed signal applied to it. Such a radiometer is shown in Fig. 3.

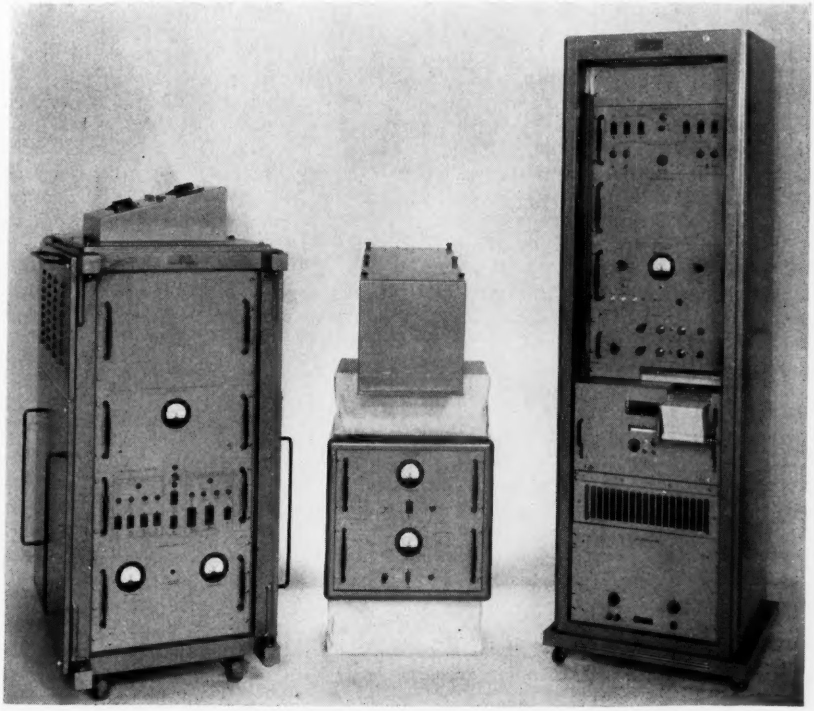


Fig. 3. This Dicke radiometer, made by Ewen-Knight Corp., employs traveling-wave tubes (in left-hand unit), and operates at 8,000 megacycles with a bandwidth of 1,000 megacycles. The upper-center unit is the switch. All parts except the control rack (right) must be mounted on the telescope antenna.

Although the circuitry is more complicated in a Dicke radiometer, the gain-stability requirements are much less than in a direct radiometer. And in cases where the gain stability desired for the latter cannot be obtained with existing technology, the only answer is to use a Dicke radiometer. Disadvantages of this method, however, are that switches which do not waste signal power are often difficult or impossible to build, and that half the power collected by the antenna is thrown away because the receiver is connected to it only half the time.

A variation of the Dicke radiometer is also used in 21-cm. work. The receiver is connected to the antenna at all times, but the incoming energy is switched between the 21-cm. frequency and a nearby frequency. The receiver noise and wide-band cosmic noise are contained in both channels, and consequently not pulsed by the switching process, but the 21-cm. radiation is in only one band and is therefore pulsed, becoming the only power to appear in the final radiometer output. Such 21-cm. radiometers are necessarily about the most complex and expensive to be found in radio astronomy. An example of these receivers is the one used by Leiden Observatory astronomers to map the spiral structure of the Milky Way.

Would not perfect gain stability in the direct radiometer or the Dicke type allow us to detect infinitesimally faint signals? With existing electronic components, the answer is no. This inescapable situation exists because receiver noise *is* noise, a random sequence of voltages, and therefore not constant in intensity. Thus, receiver noise power in the output varies

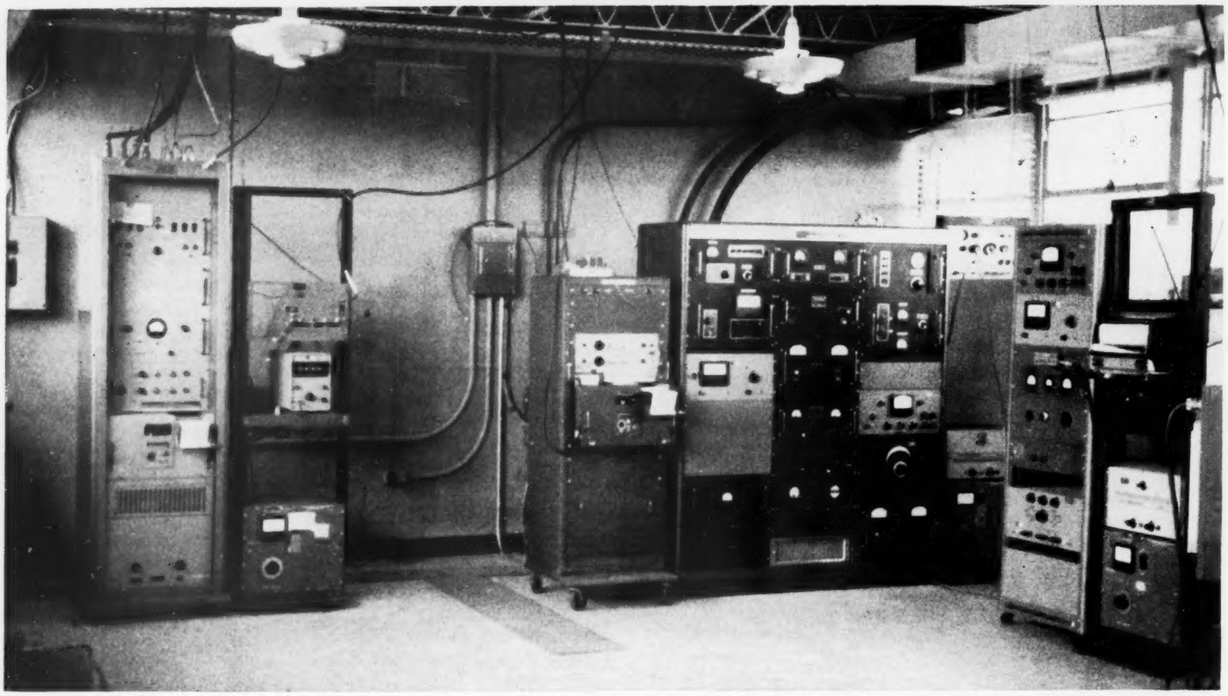


Fig. 4. This installation at the National Radio Astronomy Observatory serves the 85-foot radio telescope (pictured on page 428, June issue). The control unit of Fig. 3 is at the left, and next to it a data digitizer. At right center, the large black assembly is a direct radiometer for 20 to 27 centimeters, and a d.c.-comparison radiometer for 21 centimeters. At the far right is a 68-centimeter direct radiometer. National Radio Astronomy Observatory photograph.

with time even if the gain is absolutely constant; hence the output of a direct radiometer will vary. Similarly, fluctuations in receiver noise in the Dicke radiometer will often, just by chance, create a series of noise pulses that are synchronized with the switch-frequency generator. Here again, the radiometer output varies.

The formula that follows is probably the most famous in radio astronomy, and gives the apparent input power fluctuation, ΔP, actually caused by receiver noise:

$$\Delta P = P_R/(Bt)^{\frac{1}{2}}.$$

This value is equivalent to the fluctuation in radiometer input power that would cause the same changes in output power as are produced by receiver noise. P_R is the receiver noise power in the output divided by the gain. B is band-width, the band of frequencies accepted by the receiver, and t is the time over which the output is averaged.

In a way, measuring the average output power is like trying to determine the mean level of the ocean when it is wavy. We might do this by inserting a number of sticks in the water and reading the water level at each stick. As the ocean gets rougher, which is equivalent to an increase of the receiver noise in the formula above, our results become less accurate. But if we use more sticks in the water, equivalent to enlarging the band-width, we get a more precise answer. Similarly, by making measurements repeatedly over longer periods of time – equivalent to increasing the averaging time – our answer becomes more accurate.

The value of the receiver fluctuation given by the formula sets the ultimate limit on the sensitivity of any radiometer, since if we are to distinguish a signal it must obviously be stronger than the random fluctuations. The continuous effort to improve sensitivity is one of the most challenging and busy fields of radio astronomy. It is only because we have succeeded in reducing the fluctuations below the level of 10^{-14} watt mentioned earlier that we have been able to make radio observations at all, and our success in pushing sensitivities below 10^{-17} watt has made radio astronomy a booming science.

What can be done to improve sensitivity? The averaging time is limited by the interval an object to be observed is above the horizon. Thus, it cannot exceed something like 12 hours for many objects. However, such long averaging times are rarely used, because over long periods instabilities in electronic components produce fluctuations greater than those given by the formula. The band-width B is, of course, as large as possible. In superheterodyne receivers it cannot be made greater than about 10^7 cycles per second – values above this figure cause increases in receiver noise that lead to a net deterioration in sensitivity, despite the larger band-width. Typical superheterodyne receivers today may detect signal powers which are about 1/10,000 as strong as the receiver noise.

The effort to improve sensitivity through increasing band-width scored a major advance when a special amplifier known as the traveling-wave tube was invented. Quite different from ordinary vacuum ones, these tubes have the special characteristic of amplifying a very wide band of frequencies, for instance 10^9 cycles per second. Dicke radiometers containing very simple receivers using these tubes are becoming quite popular in radio astronomy. The receiver in Fig. 3 can detect the presence of a noise signal which increases the noise power output by only one part in 350,000!

Sometimes, however, as in 21-cm. work, the signal covers only a narrow range of frequencies. This sets a limit on the useful band-width, and the only way left to improve sensitivity is to reduce receiver noise. Much work has gone into this, mainly in an effort to improve the electronic components, such as tubes and crystals, that govern receiver noise.

Looking back over the short history of radio astronomy, it appears that sensitivity has been improved, on the average, by about 50 per cent every year. This means that each year we have been able to see about 20 per cent farther into space with a given antenna, or to study almost twice as much space as the year before. This rapid advancement may now go even faster. Larger antennas are being built more quickly. And in just the last year or so, solid-state physics has given radio astronomers an assortment of new "wonder devices" that promise startling improvements in receiver sensitivity. A description of some of these devices, which may bring another revolution in astronomy, will be given in the succeeding article.

(To be continued)

Amateur Astronomers

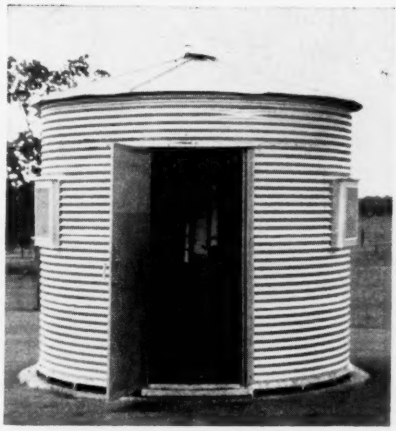
A Young Amateur's Observatory in Texas

NOBLE OBSERVATORY is the product of 3½ years of work which began when I was 14 years old, without much experience in telescope making. But the three volumes of *Amateur Telescope Making* provided me with enough information to assemble and mount a refractor large enough for detailed observations of the moon and planets.

First, a 6-inch achromatic lens was bought from a very good amateur optical worker, and an equatorial mounting procured. As presently set up, the refractor is equipped with a large finder, a 3-inch guide telescope, a 3-inch astrograph, a 35-mm. camera, an astro-camera, setting circles, and a clock drive. The last is unsatisfactory, as its output torque is insufficient to turn the telescope, so I am attempting to make another clock drive.

All of the accessories listed above, except the two cameras, were made by me from locally available materials. I provided the mounting with slow motions and clamps, and plan for the future a console unit at which the instrument can be set for any position on the sky.

I bought the building, finished as shown in the photograph, for $300. It is 10 feet in diameter, with a full-sized entrance door. One of the top sections opens to permit observing from the zenith down to about 30° altitude. Another section is for from 30° to the top of the door, and anything lower is observed through the open door. Mounted on 31 wheels, the entire observatory rotates on an angle-iron track.



The 10-foot-diameter building of Tommy May's observatory turns on 31 wheels. Inside is a 6-inch refractor.

If this project were repeated, the total cost of $900 would be much less, as I have learned a great deal. The observatory is named after Miss Charlie M. Noble, an astronomy teacher of Ft. Worth, Texas, who has pioneered in encouraging junior astronomers in this area. The observatory is open to all visitors, and correspondence concerning it is welcome.

TOMMY MAY
2422 Gibbins Dr.
Arlington, Tex.

WASHINGTON, D. C.

In the summer of 1958, several members of the National Capital Junior Astronomers began a systematic program of drawing the planet Mars. They used an 8-inch reflector and a 5-inch refractor for most of their work, which was completed last February.

From 47 drawings, an over-all map of Mars was compiled. A similar program is planned for next year. Junior groups who may be interested in conducting a project of this type are invited to write Roy R. Troxel, 3017 Cleveland Ave., Washington 8, D. C.

HUMBOLDT COUNTY, CALIFORNIA

Two amateur societies are in operation in Humboldt County, in northern California. In Eureka, the Astronomers of Humboldt recently purchased 11 acres of land for a possible observatory site. The secretary of the club is William N. Abbay, Jr., 1745 Margaret Lane, Arcata, Calif.

Founded two years ago, the Astronomers of Southern Humboldt in Fortuna has nine active members, who meet on the second and fourth Sundays at private homes. Its secretary is William Shreeve, P. O. Box 862, Fortuna, Calif.

STAMFORD, CONNECTICUT

The primary mirror of the 20-inch Cassegrainian-Maksutov telescope, described on page 622 of the September issue with the project of the Fairfield County Astronomical Society, will have a diameter of 24 inches. The 4-inch apochromatic spotting scope, another instrument of the observatory at the Stamford Museum and Nature Center, was designed by E. L. McCarthy, Perkin-Elmer Corp.

ALBUQUERQUE, NEW MEXICO

There are 12 members in the Albuquerque Astronomers. Interested persons should communicate with Dan Judd, 402 Central Ave., S.W., Albuquerque, N. M.

BURLINGTON, IOWA

Ten adults and two juniors comprise the Burlington Astronomy Club. The president is Jack R. Polson, 2214 Barrett St., Burlington, Iowa.

RIVERSIDE, CALIFORNIA

Nineteen amateurs have formed the Riverside Astronomical Society. More information is available from H. E. Kaiser, 4868 Hedrick Ave., Arlington, Calif.

THIS MONTH'S PROGRAMS

Cleveland, Ohio: Cleveland Astronomical Society, 8 p.m., Warner and Swasey Observatory. November 6, Dr. G. de Vaucouleurs, Harvard Observatory, "The Atmospheres of Mars and Venus."

Dallas, Tex.: Texas Astronomical Society, 8 p.m., Dallas Health and Science Museum. November 23, Michael Gardner, "External Galaxies."

New York, N. Y.: Amateur Astronomers Association, 8 p.m., American Museum of Natural History. November 4, Dr. George A. Morton, R. C. A. Laboratories, "New Eyes for Our Telescopes."

New York, N. Y.: Junior Astronomy Club, 8 p.m., Waverly building, New York University. November 20, Dr. Francis J. Heyden, S. J., Georgetown Observatory, "Observing Total Eclipses for Geodetic Measurements."

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Department auditorium. November 7, Dr. Jack Green, North American Aviation Corp., "Geochemical Aspects of Lunar Exploration."

BARTLESVILLE, OKLAHOMA

A new member of the Mid-States Region of the Astronomical League is the Bartlesville Astronomical Society, which is comprised of 19 amateurs. The president is E. L. Clark, 2054 Johnstone, Bartlesville, Okla.

A MICHIGAN AMATEUR'S BASEMENT PLANETARIUM

SINCE August, 1957, I have developed a small, inexpensive planetarium, with many auxiliary pieces of equipment. Although the seating capacity is only four to six, over 100 persons view the demonstrations each year, many of them returning every two months when I change the lecture subject.

So that the stars as seen from either the Northern Hemisphere or the Southern may be shown, the Spitz, Jr., projector is equipped with interchangeable spheres. These have been pierced to project 3rd- and 4th-magnitude stars not included by the manufacturer, and small holes punched together give a rather realistic impression of the Milky Way.

Half of a Spitz, Jr., sphere forms the

David DeBruyn's basement planetarium. The dome illuminator is at left.

dome illuminator, using a flashlight bulb with a blue filter. The dome is an 8½-foot beach umbrella, painted white on the inside and with linen added around the edge to complete the hemisphere. A silhouette of downtown Muskegon has been cut out, and compass points are marked.

For the sun, moon, and five bright planets, an equatorially mounted auxiliary projector with interchangeable slides was constructed. Fourteen slides depict the moon's phases, and there are slides of comets, meteors, and artificial satellites. A separate projector is used for auroras and the zodiacal light.

Photographs and other exhibits are set up outside the planetarium chamber. A phonograph with two remote speakers can be operated from the planetarium switchboard for special sound and musical effects.

DAVID DEBRUYN
2221 Oak Ave.
N. Muskegon, Mich.

Planetarium Notes

(Most planetariums give group and special showings by appointment.)

BALTIMORE: *Davis Planetarium.* Maryland Academy of Sciences, Enoch Pratt Library Building, 400 Cathedral St., Baltimore 1, Md., Mulberry 5-2370.

SCHEDULE: (Sept.-June), Thursday, 7:15, 7:45. 9 p.m.; Saturday, 2 and 3 p.m. Admission free. Spitz projector. Director, Paul S. Watson.

BLOOMFIELD HILLS, MICH.: *McMath Planetarium.* Cranbrook Institute of Science, Bloomfield Hills, Mich.

SCHEDULE: Saturday and Sunday, 2:30 and 3:30 p.m.; Wednesday, 4 p.m. Spitz projector. In charge, James A. Fowler.

BOSTON: *Charles Hayden Planetarium.* Museum of Science, Science Park, Boston 14, Mass., Richmond 2-1410.

SCHEDULE: Tuesday through Friday, 11 a.m. and 3 p.m.; Friday, 8 p.m.; Saturday, 11 a.m., 2 and 3:30 p.m.; Sunday, 1:30, 2:45, and 4 p.m. Korkosz projector. Director, John Patterson.

CHAPEL HILL: *Morehead Planetarium.* University of North Carolina, Chapel Hill, N. C.

SCHEDULE: Daily, 8:30 p.m.; also at 11 a.m. and 3 p.m. Saturday, 3 and 4 p.m. Sunday. Zeiss projector. Manager, A. F. Jenzano.

CHARLESTON, W. VA.: *Hillis Townsend Planetarium.* Children's Museum, Public Library Building, Charleston, W. Va.

SCHEDULE: Saturday, 11 a.m. Admission free. Spitz projector. Director, Mrs. R. L. Sullivan.

CHATTANOOGA, TENN.: *Clarence T. Jones Observatory.* University of Chattanooga, Brainerd Rd., Chattanooga, Tenn., MA 2-5733.

SCHEDULE: Friday, 8 p.m. Admission free. Jones projector. Astronomer in charge, Karel Hujer.

CHICAGO: *Adler Planetarium.* 900 E. Achsah Bond Dr., Chicago 5, Ill., Wabash 2-1428.

SCHEDULE: Monday through Saturday, 11 a.m. and 3 p.m.; Tuesday and Friday, 8 p.m.; Sunday, 2 and 3:30 p.m.; Tuesday through Friday, 10 a.m., special school program. Zeiss projector. Acting director, Robert I. Johnson.

COLORADO SPRINGS: *Academy Planetarium.* U. S. Air Force Academy, Colorado Springs, Colo., Granite 2-2779.

SCHEDULE: Wednesday, 8 p.m.; Saturday, 2:30 p.m. (except November 14th, 21st, and 28th); Sunday, 2 and 3:15 p.m. Admission free. Spitz Model B projector. Director, Maj. Richard J. Pfrang.

DALLAS: *Dallas Planetarium.* Dallas Health Museum, Fair Park, Dallas 10, Tex., HA 8-8351.

SCHEDULE: Saturday and Sunday, 3 p.m. Spitz projector. Planetarium educator, Mrs. Claudia Robinson.

DENVER: *Denver Museum of Natural History Planetarium.* City Park, Denver, Colo., East 2-1808.

SCHEDULE: Saturday and Sunday, 1 to 4:30 p.m. Spitz projector. Curator, W. R. Van Nattan.

FLINT, MICH.: *Robert T. Longway Planetarium.* Flint Junior College, 1310 E. Kearsley St., Flint 3, Mich., Cedar 8-1631.

SCHEDULE: Tuesday through Sunday, 8 p.m.; Saturday and Sunday, 2 p.m. Spitz Model B projector. Director, Maurice G. Moore.

FT. WORTH: *Charlie M. Noble Planetarium.* Ft. Worth Children's Museum, 1501 Montgomery, Ft. Worth, Tex., PE 2-1461.

SCHEDULE: Tuesday through Friday, 4:15 p.m.; Saturday, 11 a.m., 2:30 and 3:30 p.m.; Sunday, 2:30 and 3:30 p.m. Spitz projector. Supervisor, Norman C. Cole.

INDIANAPOLIS: *Holcomb Planetarium.* Butler University, Indianapolis 7, Ind.

SCHEDULE: Saturday and Sunday, 4 and 8 p.m. Spitz projector. Director, H. Crull.

KANSAS CITY: *Kansas City Museum Planetarium.* 3218 Gladstone Blvd., Kansas City 23, Mo., Humboldt 3-8000.

SCHEDULE: Saturday and Sunday, 3 p.m. Spitz projector. Director, Wilber E. Phillips.

LANCASTER, PA.: *North Museum and Planetarium.* Franklin and Marshall College, Lancaster, Pa.

SCHEDULE: Tuesday and Thursday, 8 p.m.; Saturday and Sunday, 2 and 3 p.m. Admission free. Spitz projector. Curator, John W. Price.

LAQUEY, MO.: *Tarbell Planetarium.* Inca Cave Park, Laquey, Mo.

SCHEDULE: Sunday, 1 to 6 p.m., continuous. Spitz projector. Director, E. D. Tarbell.

LOS ANGELES: *Griffith Observatory and Planetarium.* Griffith Park, P. O. Box 27787, Los Feliz Station, Los Angeles 27, Calif., Normandy 4-1191.

SCHEDULE: Daily (except Monday), 3:30 and 8:30 p.m.; also 2 p.m. Saturday and Sunday. Zeiss projector. Director, C. H. Cleminshaw.

MINNEAPOLIS: *Science Museum.* Minneapolis Public Library, 1001 Hennepin Ave., Minneapolis 3, Minn.

SCHEDULE: Saturday, 10 a.m. and 2 p.m. Admission free. Spitz projector. Planetarium director, Mrs. Maxine B. Haarstick.

NASHVILLE: *Sudekum Planetarium.* Children's Museum, 724 2nd Ave. S., Nashville 10, Tenn., Chapel 2-1858.

SCHEDULE: Sunday, 2:45, 3:30, 4:15 p.m. Spitz projector. Director, Jacqueline Avent.

NEWARK: *Newark Museum Planetarium.* 49 Washington St., Newark 1, N. J., Mitchell 2-0011.

SCHEDULE: Saturday, Sunday (except 1st Sunday of month), and holidays, 2:30 and 3:30 p.m. Admission free. Spitz projector. Supervisor, Raymond J. Stein.

NEW YORK CITY: *American Museum-Hayden Planetarium.* 81st St. and Central Park West, New York 24, N. Y., Trafalgar 3-1300.

SCHEDULE: Monday, 2 and 3:30 p.m.; Tuesday through Friday, 2, 3:30 and 8:30 p.m.; Saturday, 11 a.m., 1, 2, 3, 4, 5 and 8:30 p.m.; Sunday and holidays, 1, 2, 3, 4, 5 and 8:30 p.m. Zeiss projector. Chairman, J. M. Chamberlain.

PHILADELPHIA: *Fels Planetarium.* Franklin Institute, 20th St. at Benjamin Franklin Parkway, Philadelphia 3, Pa., Locust 4-3600.

SCHEDULE: Tuesday through Sunday, 3 p.m.; Saturday, 11 a.m.; Saturday, Sunday, and holidays, 2 p.m.; Wednesday and Friday, 8 p.m. Zeiss projector. Director, I. M. Levitt.

PITTSBURGH: *Buhl Planetarium and Institute of Popular Science.* Federal and West Ohio Sts., Pittsburgh 12, Pa., Fairfax 1-4300.

SCHEDULE: Daily, 2:15 and 8:30 p.m.; also at 11 a.m. Saturday and 4:15 p.m. Sunday. Zeiss projector. Director, Arthur L. Draper.

PROVIDENCE: *Roger Williams Planetarium.* Roger Williams Park Museum, Providence 5, R. I., Williams 1-5640.

SCHEDULE: Saturday, 3 p.m.; Sunday and holidays, 3 and 4 p.m. (Oct. 1-May 30). Admission free. Spitz projector. Director, Maribelle Cormack.

SAN FRANCISCO: *Morrison Planetarium.* California Academy of Sciences, Golden Gate Park, San Francisco 18, Calif., Bayview 1-5100.

SCHEDULE: Daily (except Monday and Tuesday), 3:30 and 8:30 p.m.; also 2 p.m. Saturday, Sunday, and holidays. Academy projector. Curator, George W. Bunton.

SAN JOSE, CALIF.: *Rosicrucian Planetarium and Science Museum.* Park and Naglee Aves., San Jose, Calif.

SCHEDULE: Sunday and Wednesday, 2 and 3:30 p.m. Spitz projector. Director, Rodman R. Clayson.

SANTA BARBARA, CALIF.: *Gladwin Planetarium.* Museum of Natural History, 2559 Puesta del Sol Rd., Santa Barbara, Calif., WO 6-6720.

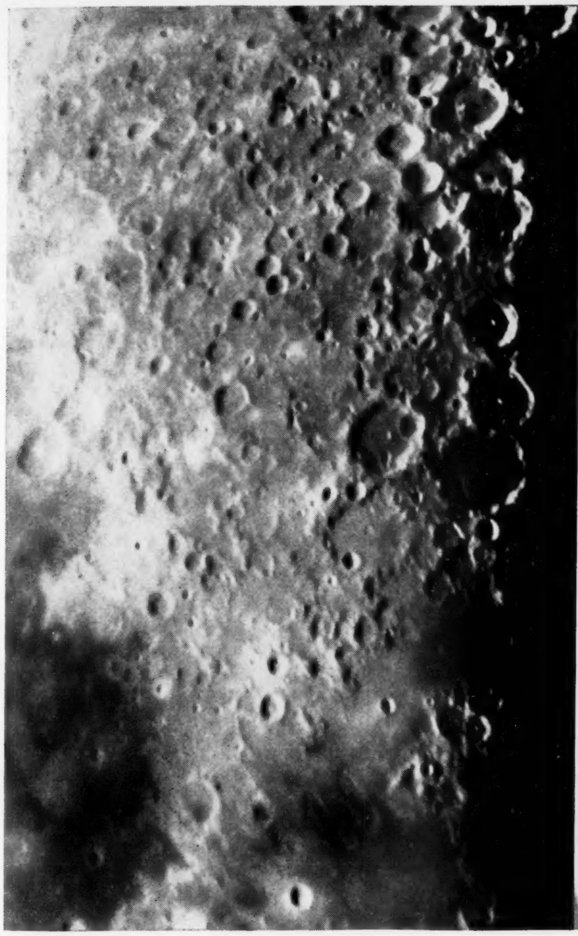
SCHEDULE: 1st and 3rd Monday, 3 p.m.; 2nd and 4th Thursday, 8 p.m. Admission free. Spitz projector. Lecturer, C. Adair.

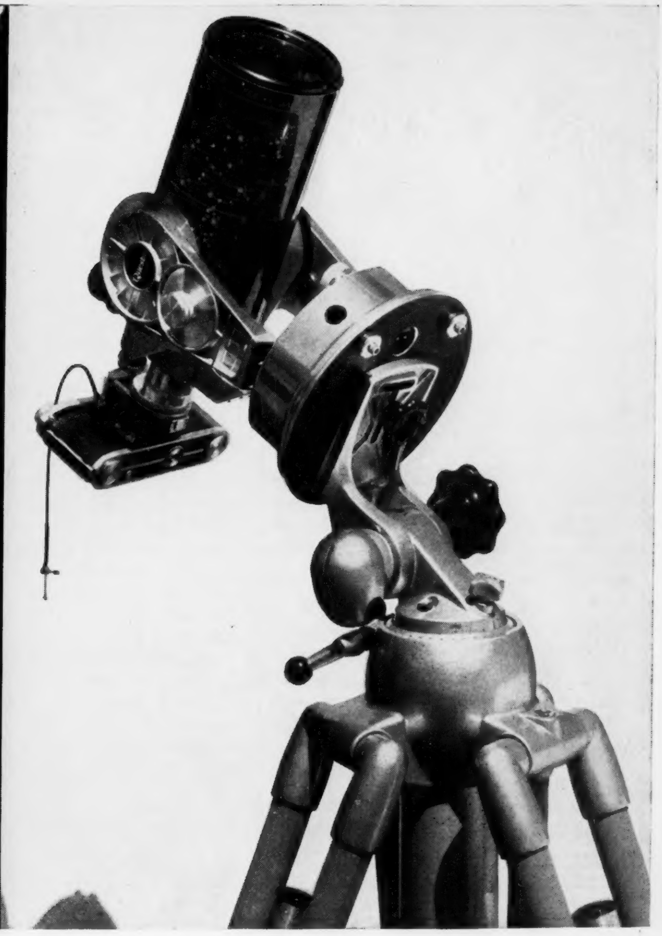
SPRINGFIELD, MASS.: *Seymour Planetarium.* Museum of Natural History, Springfield 5, Mass.

SCHEDULE: Tuesday, Thursday, and Saturday, 3 p.m.; also 8:30 p.m. Tuesday; special star stories for children, Saturday, 2 p.m. Admission free. Korkosz projector. Director, F. Korkosz.

STAMFORD, CONN.: *Edgerton Planetarium.* Stamford Museum and Nature Center, Stamford, Conn., Davis 2-1646.

SCHEDULE: Saturday, 11 a.m.; Sunday, 4 p.m. Spitz projector. Director, Ernest T. Luhde.





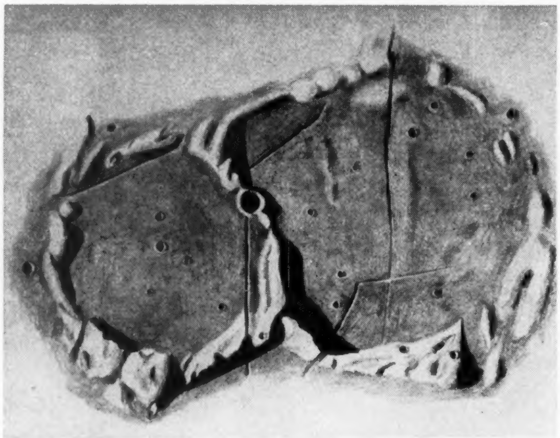
OBSERVER'S PAGE

Universal time (UT) is used unless otherwise noted.

Observing the Moon — Parry and Bonpland

LOCATED within the broad level expanse of Mare Nubium, Parry and Bonpland are members of a chain of ruined craters extending from Fra Mauro on the north to Guericke on the south. This group is seemingly older than much of the lunar surface as we now see it. While showing some traces of their former imposing magnificence, all of these formations are in some degree dilapidated.

Parry is 28 miles in diameter, according to J. Young's measurements, and is noticeably hexagonal in shape. Its walls for the most part are low, and are broken by several passes from the interior to the surrounding plain, the widest being on the west and north. The eastern wall is highest, forming a ridge that separates the floor from that of Bonpland. This ridge has several peaks reaching heights of perhaps 5,000 feet or more; a small, deep crater at its southern end is labeled Parry E in the International Astronomical Union's lunar atlas.



The lunar craters Parry (left) and Bonpland, drawn by Alika K. Herring on June 26, 1958, at 4:50 Universal time. He used a 12½-inch reflector with a power of 228x. Sunrise on this portion of the moon's surface had occurred about 16 hours before. South is at the top, east to the right.

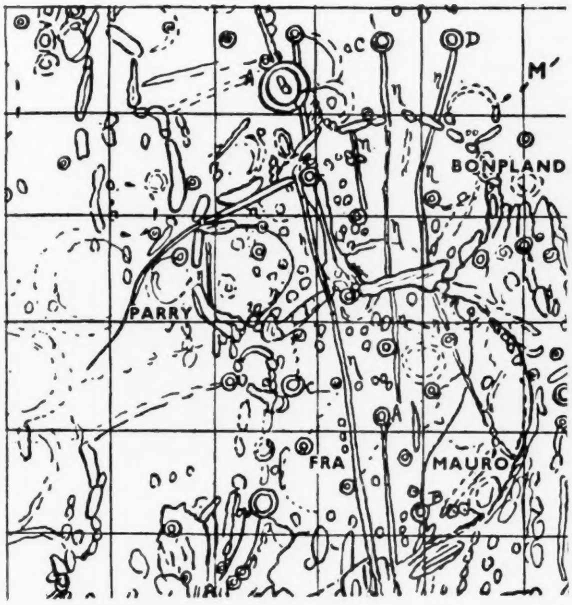
Bonpland, 37 miles across, is somewhat larger than Parry and has apparently suffered more erosion. The walls are lower, particularly on the east, where they degenerate into a broken chain of little hills. The approximate circularity of the formation (its outline has indications of polygonal structure) is broken by a large bay on the southwest. This was perhaps an ancient crater that once formed a complete ring, but the north and east walls are now missing, and I have been unable to detect the least trace of them.

The interiors of Parry and Bonpland are crossed by many rills that form part of a much more extensive system. One easily seen cleft enters Parry through a pass in the west wall, runs diagonally across its southern floor, and bends sharply southward to emerge through an opening in the south wall.

Another conspicuous cleft crosses this crater in a north-south direction near its east wall, and passes through Parry E. A northward extension cuts through the wall, and runs for some distance across the floor of adjoining Fra Mauro. The southward extension across the bay in Bonpland was hidden by the shadow of the wall at the time my drawing was made. South of Bonpland, this cleft continues some distance across the plain to end at a small crater which is designated A on H. P. Wilkins' map.

These are easy rills, and should be readily visible in 3- or 4-inch telescopes. Another, more difficult cleft traverses the eastern side of Parry's floor in a wide semicircle, concentric with the wall. To be well seen, this very delicate cleft requires fairly large apertures, optimum seeing and illumination. It is a test object for an 8-inch telescope.

The most conspicuous cleft in Bonpland crosses the floor centrally from south to north, beginning in the plain to the south at a craterlet marked C on the Wilkins map. North of the midpoint of Bonpland the cleft narrows and becomes difficult to see, but can be traced as far as the north wall. Near there, it is crossed by a delicate cleft originating



The area of Parry, Bonpland, and Fra Mauro is shown here in a reproduction of part of H. P. Wilkins' 300-inch map of the moon. South is at the top, and the grid spacing is 0.02 of the moon's radius. Compare the cleft pattern with that in the drawing opposite.

on the northeast part of the floor. After the intersection, this second one makes a sharp bend to the northwest, passing through the wall onto the floor of Fra Mauro.

Another easily seen cleft starts just south of Parry E and extends southeastward across the bay in Bonpland, but before reaching the wall it narrows and disappears on the floor.

Many other fine details are contained inside Parry and Bonpland, but are well seen only when thrown into strong relief by grazing solar illumination. Besides a number of small craterlets and hills, there are some very low ridges, generally oriented north and south. Of special interest is the curiously curved row of several saucerlike depressions, lying midway between the center and northeast wall of Bonpland.

ALIKA K. HERRING
1312 Arlington Ave.
Anaheim, Calif.

NEW VARIABLE STARS

Two recently discovered variable stars are bright enough for profitable observation in binoculars. One of them is HD 186776, in Cygnus at $19^h\ 43^m.1$, $+40°\ 36'$ (1950 co-ordinates), a 6th-magnitude object which varies by 0.7 magnitude. The other is HD 203378, in Cepheus at $21^h\ 18^m.2$, $+55°\ 14'$, which varies by 0.5 magnitude around an average value of 7.

Both stars are red, of spectral type *M*, and have light curves like that of Mu Cephei, according to the discoverer of their variability, W. Strohmeier of Remeis Observatory at Bamberg, West Germany. He first noted them while comparing patrol photographs. The two objects are shown in the Skalnate Pleso *Atlas of the Heavens*, and the first is noted as red in Norton's *Star Atlas*.

OBSERVATIONS OF A NOVA IN OPHIUCHUS

Discovery of an 8th-magnitude nova in Ophiuchus by G. Haro, of Tonanzintla Observatory in Mexico, was reported on page 343 of the May, 1958, issue of SKY AND TELESCOPE. With the aid of the photograph of the region published with that announcement, I found it easy to locate the star and follow its light changes visually.

Between June and November, 1958, the nova showed well-marked oscillations in brightness, between magnitudes 11 and $12\frac{1}{2}$. By February, 1959, when the star could again be observed in the morning sky, it was magnitude 13, fading very gradually to $13\frac{1}{2}$ by the beginning of September. These observations will be published in detail in a *Circular* of the variable star section of the Royal Astronomical Society of New Zealand, after accurate magnitudes for the comparison stars become available.

ALBERT F. JONES
40 Trafalgar St.
Timaru, New Zealand

EVERY OBSERVER with a 3-inch telescope or larger is uncomfortably aware that on some nights the moon, planets, or close double stars do not yield satisfactory images. The user of binoculars, however, generally has sharp, clear views, even when his colleague with a powerful telescope complains of poor seeing.

The term *seeing* is used to indicate the departure of the telescopic image from its ideal form. A commonly employed seeing scale ranges from 0 (hopelessly blurred) to 10 (perfect in every way). Thus, seeing 5 characterizes average conditions, in which a fair-sized amateur telescope will show considerable detail on Mars or Jupiter, but with enough atmospheric disturbance to prevent fully efficient use of a good optical system. However, all experienced planetary observers will bear poor-to-average seeing for hours on end in order to enjoy the brief moments when the image steadies down, permitting full exploitation of the telescope.

Ideally, a lens or mirror brings rays from a point on a distant object to a point in the focal plane of the telescope. Air, being a refracting medium, affects the path of the light rays according to its density, and is as much a part of the optical system as the telescope itself. Anything that alters the homogeneity of the long column of air through which the telescope looks will distort the path of the light rays.

For the purposes of the visual or photographic observer, three distinct types of seeing (I, II, and III) may be distinguished, but they can also occur in combination. This threefold classification is helpful in analyzing what can be done about seeing, for it is one of the knottier problems facing the practical observer.

In poor seeing of type I, the image changes rapidly, and small objects such as stars or Jupiter's satellites occasionally appear double or triple. On the moon or planets, the disk may show two or more distinct boundaries rapidly moving or vibrating, and surface detail seems jumpy. In addition, an out-of-focus image of a bright star shows boiling or moving streakiness.

The cause of these phenomena is air currents within or very close to the telescope, with a wave length of about one-tenth to one-half the diameter of the mirror or objective. These moving inhomogeneities within the optical path prevent rays from all parts of the mirror or objective from reaching the focus simultaneously. The effect is much as if the telescope consisted of several small mirrors in relative motion. When this trouble is present, photographic work of any delicacy is out of the question, no matter how short the exposure.

Type-II seeing is characterized by images that are steady but blurred or fuzzy. There is poor contrast on extended surfaces, and star images appear swollen, often to several times their theoretical size.

Usually type-II poor seeing results from air currents outside the telescope tube, but low-lying and often in fairly rapid motion. The wave lengths of these disturbances are small, perhaps less than half the diameter of the mirror or lens. These conditions may arise during the night cooling of air, when stable temperature layers dissipate in the presence of natural or artificial objects having different cooling rates (houses, rocks, pavement). A change of wind direction with increasing altitude may produce the same effect, if the vertical temperature gradient is steep. The passage of weather fronts often produces violent type-II disturbances. Under such conditions, lunar or planetary photography would be hopeless for any observer.

Finally, in seeing of type III the images are sharp but somewhat unsteady. A star image is crisp and clear, yet in motion; the edge of the moon ripples to some degree, although it is sharply defined. These are the effects of high-level atmospheric inhomogeneities, whose wave lengths are large compared with the aperture of the telescope, perhaps three or four times as large, or more. When

poor seeing of this type is present, there can be appreciable positional errors on photographs, since image points separated by only a few seconds of arc may be differently refracted.

Something can be done to combat the first two varieties of inferior seeing, but not the third. Seeing of type I generally results from faulty telescope design (for example, an uninsulated metal tube), heat from the observer's body, or air currents in or just above the tube. With a reflector, on very still nights, it is well to open the vents at the bottom of the tube for a while to get an approximation to thermal equilibrium, then close them to avoid slow convection currents in the interior of the tube. On windy nights, leave the vents open, as the gusts will prevent the formation of appreciable temperature gradients in the interior of the tube.

In any event, telescope tubes are best made of material with low heat conductivity and low heat capacity, to keep rapid local variations of outside air temperature from being transmitted to the tube interior, and to minimize the amount of heat so transferred. It has often been found that the performance of a telescope with a metal tube is improved by applying an interior layer of insulation, a favorite material being sheet cork.

An open or latticework tube may be helpful if it is rotatable, so that if the wind is behind the observer on a cool night, the tube can be turned to prevent his body heat from causing poor seeing of type I. However, the asymmetry of such a tube invites temperature gradients, as its material loses heat by radiation, becoming cooler than the surrounding air.

Poor seeing of type II can sometimes be cured by moving the telescope to a better location. Removal of the instrument from a downslope site will avoid the typical night drainage of turbulent cold air. Getting away from a heated building may help. Other remedies will occur to the reader who considers his own observing situation.

While nothing can be done about inferior type-III seeing, it often does not hinder delicate visual work. Photography is possible when these high-level disturbances are not too pronounced, if the exposure time is kept short compared to the period of rippling.

In summation, it is plain that seeing of type I is to a large extent remediable, that II may sometimes be ameliorated, and that III is frequently not serious enough to impair visual and photographic observation. Of course, it will often happen that the seeing, despite all efforts, is just not good, in which event it is as well to go to bed and get a good night's sleep!

FRANK VAUGHN
5801 Hammersley Rd.
Madison, Wis.

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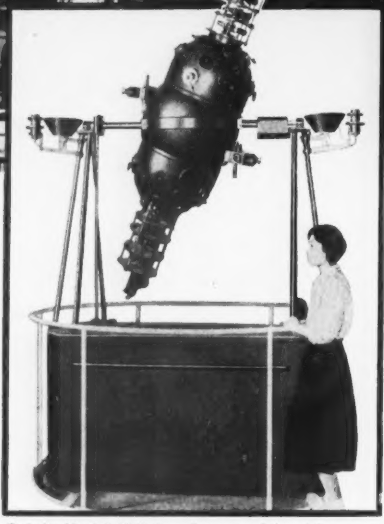

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ALDEBARAN OCCULTATION

On the night of September 22-23, the 1st-magnitude star Alpha Tauri was covered by the moon. The phenomenon was watched at the Robert T. Longway Planetarium, Flint, Michigan, by R. N. Watts, Jr., and D. Splane. They used 7 x 50 binoculars and, with the aid of a sweep-second watch they had compared with time signals, found that the star disappeared at 11:16:26.0 p.m. Eastern standard time, and reappeared at 0:19:37.5. High cirrus clouds may have affected these results.

At New Orleans, Louisiana, W. P. Searcy, III, obtained photographs of Aldebaran soon after it had emerged from behind the dark edge of the moon. His pictures were taken with a 4-inch reflector.

OCCULTATION OF NEPTUNE

The sky was very clear when I observed the occultation of Neptune by the moon on September 6th, using my 5-inch f/15 Mellish refractor. With a $1\frac{1}{4}$-inch Erfle eyepiece, the bright part of the moon was kept out of the field, but the dark side was clearly seen.

First contact occurred at 7:12 p.m. Eastern standard time. Neptune lost brightness during a little more than one second, then disappeared suddenly. The fading may have taken longer, but with the low power the planet showed only a small disk. I am anxious to hear about other observations of this event.

RENE DOUCET
650 Des Grandes Prairies Blvd.
Cap de la Madeleine
Quebec, Canada

SUNSPOT NUMBERS

The following American sunspot numbers for July and August have been derived by Dr. Sarah J. Hill, Whitin Observatory, Wellesley College, from AAVSO Solar Division observations.

July 1, 163; **2,** 121; **3,** 145; **4,** 118; **5,** 121; **6,** 113; **7,** 113; **8,** 102; **9,** 100; **10,** 84; **11,** 102; **12,** 123; **13,** 152; **14,** 152; **15,** 150; **16,** 197; **17,** 209; **18,** 178; **19,** 154; **20,** 143; **21,** 109; **22,** 104; **23,** 106; **24,** 117; **25,** 133; **26,** 156; **27,** 176; **28,** 178; **29,** 184; **30,** 197; **31,** 191. Mean for July, 141.6.

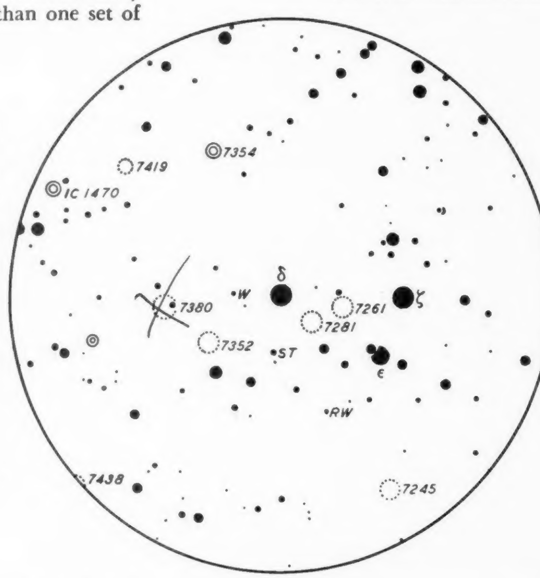
August 1, 183; **2,** 214; **3,** 204; **4,** 179; **5,** 194; **6,** 167; **7,** 173; **8,** 141; **9,** 147; **10,** 161; **11,** 144; **12,** 136; **13,** 106; **14,** 106; **15,** 134; **16,** 145; **17,** 122; **18,** 141; **19,** 162; **20,** 160; **21,** 164; **22,** 195; **23,** 192; **24,** 153; **25,** 193; **26,** 228; **27,** 253; **28,** 259; **29,** 273; **30,** 285; **31,** 261. Mean for August, 179.8.

Below are provisional mean relative sunspot numbers for September by Dr. M. Waldmeier, director of Zurich Observatory, from observations there and at its stations in Locarno and Arosa.

September 1, 290; **2,** 256; **3,** 202; **4,** 161; **5,** 148; **6,** 144; **7,** 135; **8,** 136; **9,** 157; **10,** 141; **11,** 155; **12,** 170; **13,** 148; **14,** 151; **15,** 168; **16,** 130; **17,** 87; **18,** 100; **19,** 120; **20,** 143; **21,** 132; **22,** 155; **23,** 136; **24,** 155; **25,** 105; **26,** 106; **27,** 92; **28,** 87; **29,** 80; **30,** 76. Mean for September, 142.2.

DEEP-SKY WONDERS

AROUND the famous variable star Delta Cephei draw a circle 5½ degrees in radius. Then tally up the nebulae and clusters within the area. If you are using Norton's *Star Atlas* you will find five objects, while the de luxe edition of the Skalnate Pleso *Atlas of the Heavens* will give you six. But only one of these is common to both maps, though all but one have NGC numbers; it is evidently worth while to use more than one set of observing charts.



This chart, 11 degrees in diameter and with north at the top, is based on the Skalnate Pleso "Atlas of the Heavens," but has been simplified to emphasize the location of the clusters and nebulae discussed in the text. The objects plotted in Norton's "Star Atlas" have been added in their proper positions according to the "New General Catalogue." The symbols are the same as used on the Skalnate Pleso charts.

NGC 7380 (77[8]) is the object found on both maps, at right ascension 22ʰ 44ᵐ.9, declination +57° 49′ (1950 coordinates). It is a galactic cluster of some 50 stars, 10′ in diameter, and fairly faint. While it is not mentioned in observing handbooks, it can be seen in a 4-inch telescope, though the region is difficult because it lies in the Milky Way.

The rest of the clusters plotted in Norton's are: NGC 7261, 22ʰ 18ᵐ.6, +57° 50′; 7281, 22ʰ 23ᵐ.0, +57° 35′; 7352, 22ʰ 37ᵐ.8, +57° 08′; and 7438, 22ʰ 55ᵐ.4, +54° 05′. All of them were first described by John Herschel, and the *New General Catalogue* calls them pretty large or very large. Most are now generally regarded as merely brighter portions of the Milky Way. The writer, using a 10-inch reflector, found it very confusing trying to distinguish them among the starclouds in this region.

The Skalnate Pleso shows five other objects, two of them clusters: NGC 7245, 22ʰ 13ᵐ.6, +54° 05′, a weak grouping 3′ in diameter and containing 40 stars; and NGC 7419, 22ʰ 52ᵐ.6, +60° 34′, containing but 25 stars in a 2′ diameter.

There are three planetaries in the area, the brightest being IC 1470, at 23ʰ 03ᵐ.2, +59° 59′, an 8th-magnitude object measuring 70″ by 45″, with a 12th-magnitude central star. This planetary is plotted as a very small diffuse nebulosity in the field edition of the *Atlas of the Heavens.*

NGC 7354, at 22ʰ 38ᵐ.4, +61° 01′, is of the 13th magnitude and 32″ in diameter, apparently of such low surface brightness that it is virtually impossible to find visually with amateur telescopes. I failed to observe it in three nights of searching. The unnumbered third planetary is even more difficult, being only of magnitude 14, and 8″ in diameter. It is located at 22ʰ 54ᵐ.4, +56° 54′, plotted on the accompanying chart.

WALTER SCOTT HOUSTON
Rte. 3, Manhattan, Kans.

BOOKS AND THE SKY

HANDBUCH DER PHYSIK, VOL. 53 ASTROPHYSICS IV: STELLAR SYSTEMS

S. Flügge, editor. Springer-Verlag, Berlin, 1959. 565 pages. DM 142.

ONE of the most overworked statements in the repertoire of a book reviewer is: "This book fills a long-felt need." It is, however, especially applicable to this attractive and stimulating volume on galactic structure and dynamics, galactic and globular clusters, galaxies and cosmology. So much has happened and is presently developing in these areas of research that three of the outstanding chapters in this book are on subjects that were scarcely known about a dozen years ago. One may hope that another *Handbuch* on these subjects can be written 10 years hence, for 25 years would be too long to wait. It is that time since the *Handbuch der Astrophysik* appeared.

Volume 53 should be an incentive to textbook authors to expand their offerings on galactic structure and the external galaxies. If there is any criticism to be voiced, it is that the names of H. Shapley, W. Baade, N. U. Mayall, and A. Sandage are not found in the list of authors. The first 12 chapters are in English; the last two, on cosmological theories, are in German.

F. K. Edmondson's chapter on the "Kinematical Basis of Galactic Dynamics" emphasizes that the basic kinematical principles, as stated by E. A. Milne, have been largely overlooked, with consequent troubles. The Oort double sine wave (second harmonic) in radial velocities is well known, but there is an often neglected first-harmonic term, increasing as the square of the distance from the sun, which in a typical case has about one-fourth the amplitude of the Oort term. Edmondson gives rather convincing reasons why the "low" Vyssotsky-Janssen "basic solar motion" of 15.5 kilometers per second should be used. A consistent set of galactic rotation parameters has not yet been derived. To obtain them, accurate luminosities and absorptions for distant supergiants are especially needed. These can almost certainly be obtained eventually with appropriate narrow- and broad-band photoelectric observations of such stars within and outside of selected galactic clusters.

B. Lindblad's contribution on "Galactic Dynamics" is a useful discussion of stellar mass motions, velocity distributions, and dispersions of stellar velocities with time. The final sections are concerned with spiral-structure problems and evolutionary effects. Much of the account is mathematical and not for the casual reader. The author refers to the importance of determining whether the spiral arms "trail" or "open up" and states: "From the observational point of view this question has not yet been definitely settled." The best that can be said for this statement is that it is true. Any interested reader can form his own judgment from the published observational material; the pertinent references may be found in the second de Vaucouleurs chapter in this book.

The study of galactic structure has been enormously accelerated by the development of radio astronomy. Leiden Observatory, under the leadership of J. H. Oort, is in the forefront of the spectacular 21-centimeter investigations of the dynamics and spiral structure of our galaxy. His chapter on radio-frequency studies of galactic structure is very readable but all too short, with his own contributions somewhat underemphasized. The spiral structure, derived from 21-cm. observations, is depicted in Fig. 4a (which is already out of date!), and the results from the continuous radiation observed at 1.5 meters for the whole sky are shown in Fig. 14.

The study of star clusters has always been peculiarly profitable. Because of this, the moderately long chapter by Helen S. Hogg has been written under difficulties – the literature is very extensive and many important topics need to be covered. The text is essentially nonmathematical and is delightful and informative reading for professional and amateur astronomers alike.

A comparison with Shapley's 1933 *Handbuch der Astrophysik* chapter on the same subject reveals how much has been learned in 25 years. The last decade has been especially fruitful, with the development and application of new photoelectric techniques in the Southwest and at Pacific Coast observatories. Mrs. Hogg gives only a short discussion of stellar associations, a subject that might well take a chapter of its own.

Very useful catalogues of 514 galactic clusters and 118 globular clusters are given in two appendices. The care with which such listings must be compiled is illustrated by the position of NGC 7790, correctly given here, but erroneously noted in the earlier literature. The new position "moves" this cluster to an area of the sky (it was there all the time!) that includes three classical Cepheids and one eclipsing binary, with a number of consequent important cosmological implications.

The next two sections are "Discrete Sources of Cosmic Radio Waves" by R. Hanbury Brown and "Radio Frequency Radiation from External Galaxies" by B. Y. Mills. Radio astronomy has always suffered from poor resolving power, which makes "radio star" positions inexact, identifications very difficult, and angular size usually impossible to measure. This condition is accentuated because many radio telescopes have a complex pattern

of side lobes. Furthermore, the radio energy drops rapidly toward shorter wave lengths where the resolving power is higher. There is marked disagreement, for example, between the Cambridge University and the Australian surveys over a common area of the sky, not only regarding positions of discrete sources but their numbers as one goes to smaller and smaller flux densities.

Of the relatively few discrete sources that have been optically identified and investigated, some have yielded results and implications so exciting as to earmark these sources as an extraordinarily fertile subject for research. These two chapters together, with some overlap, give an excellent account of the techniques, problems, often contradictory results, and future hopes in this rapidly changing radio work, which depends so much on enormous instruments and the most sensitive detectors.

The next two chapters, by G. de Vaucouleurs, concern the galaxies, their classification, morphology, and general physical properties. This is a field in which de Vaucouleurs himself has made many fundamental contributions, despite the handicap of the comparatively limited instrumentation available to him in the Southern Hemisphere. The pages are liberally sprinkled with beautiful reproductions from the soon-to-appear Hubble memorial volume. The main revisions in Hubble's classification system are given, as well as de Vaucouleurs' own three-dimensional plan, the additional third "dimension" being ring or spiral structure.

Two short contributions by F. Zwicky on "Multiple Galaxies" and "Clusters of Galaxies" are written in the vigorous style associated with this author. I could find no reference by Zwicky to the important and extensive investigations of George Abell on clusters of galaxies. Zwicky's work on multiple galaxies leads him into considerable disagreement with other astronomers concerning the effects of galactic collisions. A 200-inch photograph and a diagram of a cluster of galaxies are given in which the density approaches the somewhat fantastic value of 250,000 galaxies per square degree. Zwicky refers to galaxy red shifts as symbolic velocities of recession, calls attention to the mere handful of observers having access to large telescopes (with consequent slow accumulation of data and difficulty in obtaining independent observational checks), and correctly warns against drawing any too precipitous conclusions from often necessarily scanty data.

The next chapter, on the large-scale organization of the distribution of galaxies, by J. Neyman and Elizabeth L. Scott, is presumably concerned with some of the same problems as those in Zwicky's chapters, but the approach is very different. These authors' statistical analyses have been stimulated by the Shane-Wirtanen survey with the Lick 20-inch astrograph, which covers the sky from the north pole to declination $-23°$. Many of these six-by-six-degree plates have thousands upon thousands of extragalactic images on them; most of the counts have been made and already some of the analyses have been published.

G. C. McVittie's contribution concerns the observational basis of cosmology, and is refreshing because we find here a theorist who is properly skeptical of the observational data. The chapter is well written and deserves careful study. It was prepared three years ago, and since then many photoelectric investigations of clusters, Cepheids and the Magellanic Clouds have strengthened the observational picture. Continued photoelectric researches in the Magellanic Clouds are especially needed, but the number of photoelectric observers who are working at 19th and 20th magnitude in these uniquely important galaxies is very small.

The last two chapters concern various theoretical cosmologies. Written by O. Heckmann and E. Schücking, they require a knowledge of both German and tensor analysis, and will therefore be rather heavy going for the average astronomer trained in this country.

JOHN B. IRWIN
Goethe Link Observatory
Indiana University

Films and the Sky

THE STORY OF THE UNIVERSE UNIT I: THE EARTH AND ITS MOONS

Harlan J. Smith. Films for Education, New Haven, Conn., 1959. Six filmstrips, $36.00.

WITH THE ADVENT of the age of space travel, astronomy is becoming an ever more popular subject and is assuming its proper place as an integral part of the elementary science curriculum. Science teachers, many of whom have little background in astronomy, are now required to conduct a unit in this subject. Planetarium demonstrations, television programs, and other popular presentations of astronomy are drawing larger audiences than ever before. These trends produce an increasing demand for quality teaching aids.

The Story of the Universe is a series of color filmstrips produced by Films for Education. While intended for an upper-grade school audience, the strips contain enough variety of pictorial material to be interesting to still younger groups. Also, the technical content and broad coverage make these films suitable for high school classes, adult laymen, and even college survey courses for nonconcentrators in astronomy.

Following the traditional approach to the study of astronomy, the series begins with the earth and proceeds outward. Unit I, "The Earth and Its Moons," contains six filmstrips.

1. "The Earth's Shape and Size" (56 frames) deals with several methods used by the ancients to prove that the earth is spherical and to measure its circumference. How their proofs and measurements are borne out by modern science is also shown.

2. "Motions of the Earth in Space" (65 frames) proceeds from a discussion of motion in general to a description of the rotation and revolution of the earth. As in the first strip, proofs from observed happenings are stressed.

3. "The Earth as a Planet" (67 frames) discusses the atmosphere's mass, density, and composition, and explains the radio-reflecting properties of the ionosphere. Causes of the seasons are also illustrated.

4. "Exploring the Space Around the Earth" (59 frames) first describes conventional aircraft propulsion and its inadequacies for travel beyond the earth's atmosphere. The section on rockets contains a thorough discussion of the law of action and reaction. Orbits and their properties are treated, as well as escape velocity.

5. "Information from Satellites" (63 frames) begins with the uses of artificial satellites. Radiation measurement raises the subject of the kinds of radiation man will encounter in space travel. Condi-

tions in a spaceship — especially weightlessness — are touched upon, leading to an explanation of the difference between mass and weight. Finally, the space station and rockets of the future are mentioned.

6. "The Moon" (72 frames) reviews the composition of the moon, conditions on its surface, and its gravitational attraction. The moon's motion as a satellite — its distance and orbit — are explained along with its phases and influence on the tides. The question of why we always see the same side of the moon is answered, and some prominent lunar features are described.

Perhaps the most impressive aspect of the entire series is the excellent artwork in all the slides. The text is brief, compact, and well written. Clarity and continuity are stressed throughout. Frames of review questions are placed at intervals, providing an opportunity to test the effectiveness of the previous presentation. Coverage is as thorough as is required, and basic concepts of physics are introduced and explained where they apply to the astronomical topic presented.

The continuity of topics and text within the individual strips and among the films of the series is most helpful to the teacher with little knowledge of astronomy. For the lecturer already familiar with the fundamentals of astronomy, a series of separate slides would probably be preferable for talks on selected subjects.

The Story of the Universe is designed as an introduction to astronomy, and Unit I, "The Earth and Its Moons," makes an excellent beginning toward the fulfillment of this purpose.

Orders for films and requests for further information should be addressed to Films for Education, Audio Lane, New Haven, Conn. Prices are $7.50 for each strip, $36.00 for a unit of six filmstrips, and $144.00 for the entire set of four units. Units II, III, and IV are now in production.

VALERIE A. ROBERTS
Charles Hayden Planetarium

NEW BOOKS RECEIVED

HOW OLD IS THE EARTH? *Patrick M. Hurley*, 1959, *Doubleday*. 160 pages. 95 cents, paper bound.

Modern knowledge of the age, origin, and structure of our planet is described by a leading geologist for the scientifically minded layman and for students. There is an explanation of dating rocks by their radioactivity.

This book is one of the new science study series being issued by the Physical Science Study Committee, formed in 1956 to improve secondary-school science teaching in the United States. Other books in the series are *The Neutron Story*, by Donald J. Hughes; *Magnets*, by Francis Bitter; *Echoes of Bats and Men*, by Donald R. Griffin; and *Soap Bubbles*, by C. V. Boys.

THE SUN, *Karl Kiepenheuer*, 1959, *University of Michigan Press*. 160 pages. $5.00.

How the sun is observed and recent findings about solar phenomena are the themes of an illustrated book written in nontechnical language by an expert. This is a translation of a work first published in Germany in 1957.

CONTEMPORARY GEODESY, *Charles A. Whitten* and *Kenneth H. Drummond*, editors, 1959, *American Geophysical Union*, 1515 Massachusetts Ave., N.W., Washington 5, D. C. 95 pages. $5.50.

This volume contains the proceedings of a symposium on contemporary problems in the measurement of the size and shape of the earth. Satellites and other recent advances have accentuated the need for an international geodetic network. The symposium took place at the Smithsonian Astrophysical and Harvard observatories in December, 1958, with 107 scientists attending.

ASTRONOMISCHER JAHRESBERICHT, Vol. 57, 1959, *Astronomisches Rechen-Institut*, Heidelberg, West Germany. 525 pages. DM 60, paper bound.

The world's astronomical literature published in 1957 is comprehensively listed in this latest annual volume of a standard reference work. Titles are arranged by subject, with short abstracts in German for the more important references. The alphabetical subject index is in English.

THE REALM OF THE NEBULAE, *Edwin Hubble*, 1958, *Dover*. 207 pages. $1.50, paper bound.

This is a photo-offset reprint of Hubble's classic book of 1936, in which he reviewed the observational evidence that galaxies are other star systems, and summarized his findings as to their distances, sizes, and distribution in space.

While this work remains a landmark in the history of science, much of its contents is out of date. Hubble's scale of distances of galaxies, upon which most of his numerical conclusions depend, is now undergoing drastic revision. Hence the book should be read with caution, and cannot be recommended as a reference for numerical data.

SPACE TECHNOLOGY, *Howard S. Seifert*, editor, 1959, *Wiley*. 1,151 pages. $22.50.

This systematic textbook for graduate students covers the engineering basis of artificial satellites and space travel. The treatment is in five broad categories: flight dynamics, propulsion and structure, communications and guidance, psychophysical and biological problems of space travel, and research in space physics. The material is based on a course given by the University of California in co-operation with Space Technology Laboratories.

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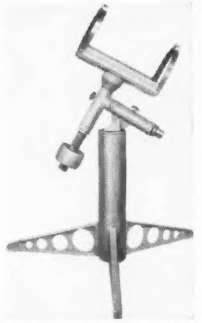

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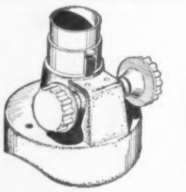

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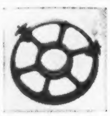

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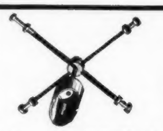

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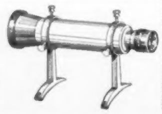

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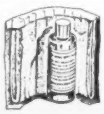

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GLEANINGS FOR ATM's

CONDUCTED BY ROBERT E. COX

A Low-Power Microscope System for High Magnifications

During the 1958 opposition of Mars, for my evening astronomy class at the Wilke Observatory of Macalester College, I tried projecting the planet's image directly from the telescope onto a white screen. The 8-inch f/8 reflector and a good 1-inch eyepiece gave a much larger and brighter image than I had thought possible.

Since the 8-inch reflector is Springfield mounted for the observing convenience of visitors and students, the focal plane is not extended very far from the last prism in the optical train. This helps reduce the size of the prisms and lowers diffraction and light loss. However, it prevents the use of a Barlow lens for increased magnification, and all high powers have heretofore been obtained using short-focal-length eyepieces with little eye relief.

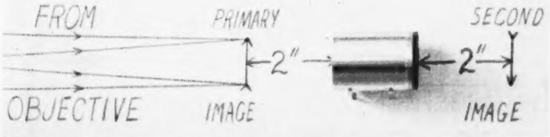
While looking at the projected image, the thought suddenly occurred to me that here was half of the optical system of a low-power microscope. If another eyepiece were placed behind the image, in place of the projection screen, then it would be viewing the enlarged image with a great increase in magnification.

In an ordinary microscope, an objective of short focal length is used to form an enlarged image of an object by projection, the image then being examined by a magnifier or eyepiece. While conventional microscopes have a standard separation between the optics, here that spacing could be varied over a wide range to give a corresponding range in amplification. Experience has shown that this arrangement is practical.

The explanation of the method is simple. In a telescope, an eyepiece with an EFL (equivalent focal length) of 1" has its principal plane 1" from the image formed by the main objective, and the emerging beams of light are parallel. If the eyepiece is withdrawn twice its focal length from the primary image, in this case 2", it will project a secondary image equal in size to the primary one, but inverted and 2" behind the eyepiece. This system would have no amplification, only transferring the image to a position some 4" or 5" from the primary focal plane (the thickness of the eyepiece assembly must be added, too).

Dr. Sherman Schultz, Jr., demonstrates his method of amplifying telescope magnification, on the 8-inch reflector at the Wilke Observatory of Macalester College. He uses a positive lens at the diagonal eyepiece holder, and the ocular is at the end of the long extension tube. The author has supplied all photographs with this article.

If the eyepiece is slowly brought closer to the primary image, the projected image swiftly moves to a greater distance and its size increases. In a 1-inch projection system, the amplification is half the distance between the eye lens of the eyepiece and secondary image. Thus, if the image is 4" away, its size will be doubled; 6", tripled. The use of another 1-inch eyepiece to



A 1-inch eyepiece placed to act as a transfer lens with no amplification. Note that the new image has been erected.

For extreme amplifications one or more $1\frac{1}{4}''$ tubes may be coupled together. Here two of them are joined by a piece of metal tubing. With a 1-inch projection lens at the left, and a 1-inch eyepiece at the right, this arrangement increases the magnification by a factor of about six.

view the projected image will yield respective powers two and three times normal for the telescope used. If a $\frac{1}{2}$-inch eyepiece is used to view the projected image, the power will be increased four and six times, respectively.

Since eyepieces are designed primarily to emit parallel light, I decided to try a system that was specifically designed for projection purposes, and selected a good f/1.6 8-mm. motion-picture projector lens of 1" focus. But no perceptible difference in image quality could be detected in comparison with a good orthoscopic eyepiece. Therefore, if you have an excellent ocular that can be used as a projection lens, it is unnecessary to buy any extra optics.

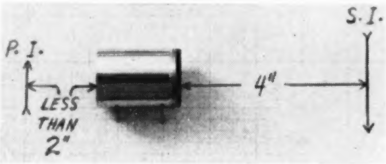
The table shows the amplification effect with various eyepiece combinations and separations, using a 1-inch eyepiece for projection.

TABLE OF AMPLIFICATION

Distance of projected image	*Viewing eyepiece* 1-inch	½-inch	¼-inch
2"	1x	2x	4x
4"	2x	4x	8x
6"	3x	6x	12x

For assembling the low-power microscope unit, chrome plumbing tubing is quite suitable. It comes with an outside diameter of $1\frac{1}{4}''$ along most of its length, and the flared-out section at one end has an inside diameter of $1\frac{1}{4}''$. To prevent internal reflections the inside should be painted black. If necessary, several tubes can be fastened together by couplings, as shown in the picture above.

The method of mounting the unit will depend on the construction of the projection eyepiece. If the eye cap can be removed without disturbing the eye lens, then the eyepiece can be slipped into the $1\frac{1}{4}''$-inside-diameter section of tubing. If this cannot be done, then a little more ingenuity must be used. Be sure that the



If a 1-inch eyepiece is used, it must be placed less than two inches from the primary image to project an image that is enlarged—two times in this example.

eye lens of the projection eyepiece is turned toward the new image plane.

Has this system any advantages over the use of a Barlow lens? First, if you already have good eyepieces, it is not necessary to purchase any more optical parts. Second, since the usual Barlow's diameter is smaller than that of the incoming cone of light from the primary mirror, there is a decided narrowing of the field and also vignetting. Because the low-power microscope system is placed behind the focus at a position where it intercepts the full cone of light from the primary, it has a minimum light loss and vignetting. Third, from two or three good eyepieces almost any reasonable power can be secured with a modest collection of extension tubes. These eyepieces need not be high-power ones, probably no shorter than a ½-inch.

It is most important to keep the tubes mechanically stable and rigid, as bending can cause serious image distortion and poor focus. The Springfield mounting, with its stationary eyepiece location, is especially suited for this system. On German- or fork-mounted Newtonians, care should be taken not to overbalance the telescope, setting up unwanted vibrations.

SHERMAN W. SCHULTZ, JR.
944 Cobb Rd.
St. Paul 17, Minn.

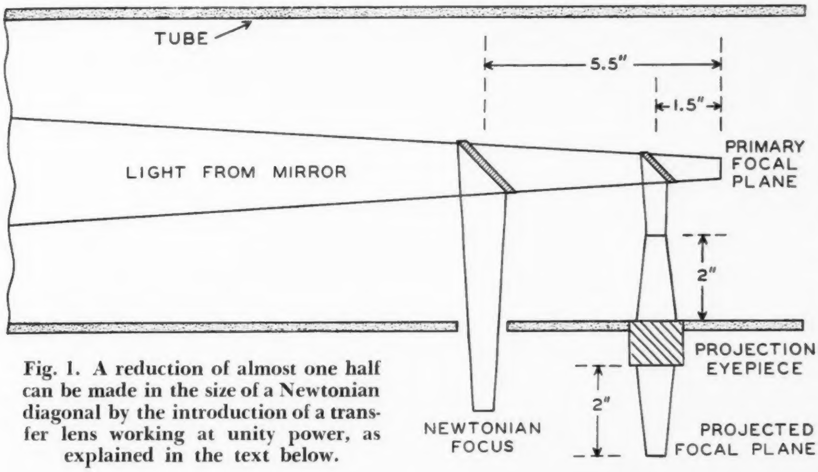


Fig. 1. A reduction of almost one half can be made in the size of a Newtonian diagonal by the introduction of a transfer lens working at unity power, as explained in the text below.

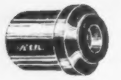
SOME ADVANTAGES OF A TRANSFER LENS

DR. SCHULTZ'S method of projecting the prime-focus image of a telescope has important advantages when the object and image are equidistant from the projection lens. Then it simply transfers the image from one focal plane to another, without change in magnification. If the lens is of good quality, no serious aberrations are introduced by the transfer.

With this system, a smaller diagonal can be used in a Newtonian reflector. Fig. 1 shows a 6-inch reflector fitted with a 1-inch orthoscopic eyepiece as a transfer lens. The diagonal would normally be placed 5.5" inside the primary focus, and it would have a minor axis of 1.11". With the transfer lens, the diagonal need be only 1.5" inside the primary focus, and its shortest diameter can be 0.65". Only 1.2 per cent of the incoming light is blocked by this diagonal, instead of 3.4, and there is less diffraction from the shorter circumference. It is also possible to place a field stop near the new focal plane to remove stray light during daytime observing.

In designing a Newtonian that uses a positive lens to reduce diagonal size, care should be taken that the focus is either in front of or entirely behind the diagonal itself. Were any part of the flat mirror to lie in the transfer-image plane,

Mounted Eyepieces



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27 mm. (1-1/16")	Kellner	**4.50**
32 mm. (1¼")	Orthoscopic	**12.50**
35 mm. (1⅜")	Symmetrical	**8.00**
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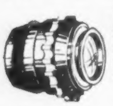

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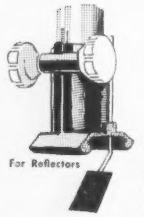
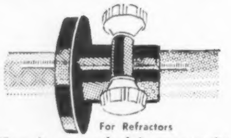


For Reflectors



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We can supply ALUMINUM TUBING for the lenses above.

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We have the largest selection of diameters and focal lengths in the United States available for immediate delivery. These are perfect magnesium-fluoride coated and cemented Gov't. surplus lenses made of finest crown and flint optical glass. Not mounted. Fully corrected. Tremendous resolving power. They can readily be used with eyepieces of only ¼" focal length, thereby producing high powers. Guaranteed well suited for astronomical telescopes, spotting scopes, and other instruments. Gov't. cost up to $100.

Diameter	Focal Length	Each	Diameter	Focal Length	Each
54 mm. (2⅛")	254 mm. (10")	**$12.50**	83 mm. (3¼")	660 mm. (26")	**$28.00**
54 mm. (2⅛")	300 mm. (11.8")	**12.50**	83 mm. (3¼")	711 mm. (28")	**28.00**
54 mm. (2⅛")	330 mm. (13")	**12.50**	83 mm. (3¼")	762 mm. (30")	**28.00**
54 mm. (2⅛")	390 mm. (15.4")	**9.75**	83 mm. (3¼")	876 mm. (34½")	**28.00**
54 mm. (2⅛")	508 mm. (20")	**12.50**	83 mm. (3¼")	1016 mm. (40")	**30.00**
54 mm. (2⅛")	600 mm. (23½")	**12.50**	102 mm. (4")	876 mm. (34½")	**60.00**
54 mm. (2⅛")	762 mm. (30")	**12.50**	108 mm. (4¼")	914 mm. (36")	**60.00**
54 mm. (2⅛")	1016 mm. (40")	**12.50**	110 mm. (4⅜")*	1069 mm. (42-1/16")	**60.00**
54 mm. (2⅛")	1270 mm. (50")	**12.50**	110 mm. (4⅜")	1069 mm. (42-1/16")	**67.00**
78 mm. (3-1/16")	381 mm. (15")	**21.00**	128 mm. (5-1/16")*	628 mm. (24¾")	**75.00**
80 mm. (3⅛")	495 mm. (19½")	**28.00**	128 mm. (5-1/16")	628 mm. (24¾")	**85.00**
81 mm. (3-3/16")	622 mm. (24½")	**22.50**	*Not coated		

● We can supply ALUMINUM TUBING AND CELLS for the lenses above. ●

NEW! 6" LENSES

Our 6" objective does not need high-pressure salesmanship. Its sparkling performance speaks for itself. Test one, or have any qualified person test it; we are certain that you will be satisfied. If not, take advantage of our money-back guarantee.

6"-DIAM. AIR-SPACED TELESCOPE OBJECTIVE

Hard-coated on 4 surfaces

f/10 - 60" focal length { MOUNTED .... **$175.00** / UNMOUNTED .. **150.00** }

f/15 - 90" focal length { MOUNTED .... **175.00** / UNMOUNTED .. **150.00** }

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8-POWER ELBOW TELESCOPE

8 x 50

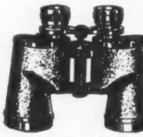
This M-17 telescope has a brilliant-image 48° apparent field — 325 feet at 1,000 yards. The telescope can be adjusted for focusing 15 feet to infinity. It has a 2" objective, focusing eyepiece 28-mm. focal length with an Amici erecting system. Turret-mounted filters: clear, red, amber, and neutral. Lamp housing to illuminate reticle for nighttime use. Truly the biggest bargain you were ever offered. Original Gov't. cost $200.

BARGAIN PRICE Uncoated **$13.50 ppd.** Coated **$17.50 ppd.**

Coated Binoculars

Beautifully styled imported binoculars. Precision made.

LOW, LOW PRICES!



American Type

"Zeiss" Type

Complete with carrying case and straps. American type offers a superior one-piece frame and clean design.

Size	Field at 1,000 yards	Type	Center Focus	Ind. Focus
6 x 15	360 ft.	Opera	—	**$12.75**
6 x 30	395	"Zeiss"	**$18.75**	**16.75**
7 x 35	341	"Zeiss"	**20.75**	**17.95**
7 x 35	341	American	**23.50**	—
7 x 35	578	Wide-Angle 11°	**35.00**	—
7 x 50	372	"Zeiss"	**24.95**	**22.50**
7 x 50	372	American	**32.50**	—
8 x 30	393	"Zeiss"	**21.00**	**18.25**
10 x 50	275	"Zeiss"	**28.75**	**26.75**
20 x 50	183	"Zeiss"	**33.75**	**31.75**

All prices above plus 10% Federal tax.

GIANT "3" inch TELESCOPE

40 POWER

ALL LENSES COATED

HIGH-POWER SCOPE AMERICAN MADE

Big 3"-diameter, achromatic, coated objective will give you the brightest crystal-clear images. Micrometer spiral focusing drawtube, lightweight aluminum construction throughout, tough black crackle finish. Length open 22", closed 15½". Upright image. Guaranteed to perform flawlessly. **$57.50 ppd.**

TRIPOD FOR TELESCOPE ABOVE

Sturdy, lightweight, all-metal, black crackle finished tripod. Ball-swivel joint allows easy directional adjustments. Equipped with a standard ¼ x 20 stud which will fit any photo tripod. Stands 11" high, weight 1½ lbs. Comes with web straps. **$8.95 ppd.**

● **"MILLIONS" of Lenses, etc.** ●
Free Catalogue

We pay the POSTAGE in U. S. — C.O.D.'s you pay postage. Satisfaction guaranteed or money refunded if merchandise returned within 30 days.

A. JAEGERS

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dust or surface imperfections would be in focus in the final image.

Springfield-mounted telescopes can also benefit from transfer lenses. Instead of the large diagonal mirror conventionally employed to bring the light down the declination axis, a significantly smaller flat can be used. With careful design, a transfer lens of several inches focal length allows the primary diagonal to be reduced in size in the same proportion as in our example of the Newtonian reflector.

Horace E. Dall has designed a compound telescope in which the secondary focus is between the primary and secondary mirrors, but is brought to a new focus behind the primary by a high-quality triplet lens. (This plan is described in *Scientific American* for May, 1939; December, 1947; September, 1951; and April, 1952.) The image is erect and a field stop permits daytime viewing even with an open tube. I built an 8-inch reflector of this type, and obtained fine results with a war-surplus erecting system for a unity-power transfer lens. I use a 2-inch secondary mirror and a field stop, and for terrestrial viewing the brilliance and color rendition of the images leave little to be desired.

Perhaps the most interesting application of a positive transfer lens is a pancratic system — one with alternative effec-

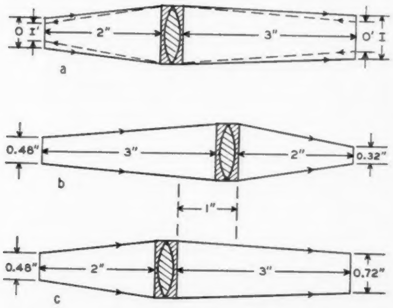


Fig. 2. The principle of a pancratic lens system, part "a" showing the reversibility of the light paths, while "b" and "c" illustrate actual systems. If the focal planes are to remain fixed, the projection lens may be placed in only two positions.

tive focal lengths but having fixed focal planes. This is made possible by the action of conjugate foci and the reversibility of a light path in an optical system. In Fig. 2a, a triplet lens of about 1.2" focal length is 2" from an object and forms an image 3" on the other side of the lens. If the object is transferred to the image plane, light passing in the reverse direction through the lens (dashed lines in the drawing) will form a new image 2" from the lens. But the sizes of the images will be different, the one nearer the lens being the smaller.

Figs. 2b and 2c show the application of such a lens to the Newtonian reflector of Fig. 1. If the focal length of the primary mirror is 48" and the image size 1/100

of this or 0.48", it will cover 34.3 minutes of arc. A pancratic transfer lens, if 3" from this image (Fig. 2b), forms a new focus 2" behind the lens, and the image size is 0.32". A 1-inch eyepiece that gave a power of 48x on the original image now gives 32x, only ⅔ as much.

When the lens is moved to 2" from the primary image, the new focus is 3" behind the lens. Now the image that was originally 0.48" in diameter becomes 0.72", an increase of 1½ times; the 1-inch eyepiece will give 72x. Shifting the projection lens by 1" more than doubles the image size. With the flick of a finger, the observer can change the power of any eyepiece by a factor of 2¼. It is startling to see this change in the field of view, especially when observing the moon. In practice, the pancratic arrangement should be restricted to small movements of the lens.

To determine the focal length, f, of a lens suitable for a particular set of object and image distances, o and i, we may use

$$1/f = 1/o + 1/i.$$

In our example, o is 2 and i is 3, giving 1/0.833 for $1/f$, whereby $f = 1.2$, the focal length of the lens in inches.

The projected image size, I, is given by $I = O\,i/o$, where O is the size of the object, that is, of the primary image before projection.

Because of the short focal lengths involved, an extremely high-quality transfer lens is required in a pancratic system. Two achromats of twice the desired focal length might work if placed crown lens to crown lens. Hastings triplets, designed for magnifiers, are generally of low quality, as they are mass-produced.

Hold the primary-focus image plane diameter to about 1/100 the telescope's focal length, or curvature of field and distortion may make the projection system impractical.

R. E. C.

TELESCOPE CAMERA HOLDER

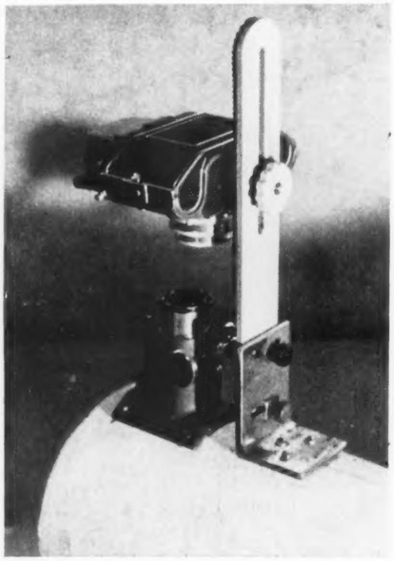
A HOLDER for securing a 35-mm. camera over the eyepiece of a reflecting telescope can be made quite inexpensively — perhaps for only two dollars. The basic parts are angle iron, a photoflash unit arm, and nuts and bolts.

A 2" piece of angle iron is cut from a length of 2"-by-3" stock. In the 2"-by-2" leg, a triangle of ¼" holes is drilled, and in the other leg two 1¼"-by-¼" slots are cut 1½" apart, as seen in the picture. This iron bracket is attached to the telescope tube so that the camera, when mounted, will be squarely over the eyepiece.

The photoflash unit arm is held to the bracket with 1" bolts, the slots allowing it to be moved sideways. The camera is then fixed to the arm with a tripod-screw attachment.

This unit is best suited to a single-lens reflex camera. When taking pictures the lens is set at infinity; the eyepiece is focused sharply by eye; then the camera is eased down until the image is clearest.

GEORGE D. CARTER, JR.
1885 Glendale Dr.
Denver 15, Colo.



George Carter's arrangement for supporting a particular camera. Adjustment for different cameras would be provided by slots in the angle iron where it is fastened to the telescope tube (lower right in the picture).

FIRST STEP TO FINER PERFORMANCE!

Easy, Low-Cost Way To Enjoy Thrills Of Astrophotography

Convert your present 35-mm. camera with this new adapter

Developed by Criterion especially for single-reflex 35-mm. cameras with interchangeable lens. Simply remove present lens mount and add this precision-made achromatic lens that adapts camera to eyepiece of any telescope — refractor or reflector. When ordering, *be sure to specify make of your camera.*

For 35-mm. cameras with SCREW-TYPE lens mount
Cat. #CPA-36 for 1¼" eyepiece holders..**$19.00**
Cat. #CPA-37 for 4" standard Dynascopes **$17.50**

For 35-mm. cameras with BAYONET-TYPE lens mount
Cat. #BPA-36 for 1¼" eyepiece holders..**$22.50**
Cat. #BPA-37 for 4" standard Dynascopes **$21.00**

New!

Dyn-o-Astro 35-mm. Camera

at less than regular price of camera alone!

No need to be an expert photographer to take exciting astrophotos with this *single-reflex*-type, precision-made 35-mm. camera. No complicated settings. No plates or filmholders to load and unload. No worries about missing target. Large focusing screen shows you *exactly* what you are shooting, right up to moment you take the picture. Includes such advanced features as:

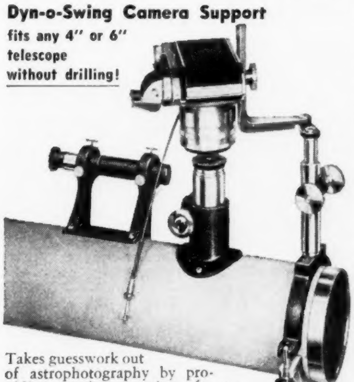
— No accidental double exposures. Winding knob automatically advances film, positions mirror, winds shutter, counts exposures.
— Dual-speed setting knob controls both fast and slow shutter speeds. Color coding makes mistakes impossible.
— Integrated magnifier for critical focusing even on dim objects.

Takes time exposures and also has speeds up to 1/500 second. Guaranteed for 2 years. Complete, ready for use.

Model CP-35 fits 1¼" eyepiece holder **$89.00 postpaid**
Model CP-36 fits all standard 4" Dynascopes **$85.00 postpaid**

Dyn-o-Swing Camera Support

fits any 4" or 6" telescope without drilling!



Takes guesswork out of astrophotography by providing *precise centering* of camera over eyepiece. Smooth rack-and-pinion adjustment. Easily attached or detached from tube, with rigid clamp for maximum stability. Special arm lets you swing camera away from eyepiece for visual observation, with instant return for photographing. Can be used with almost any camera. Postpaid.

Cat. #CS-4 to fit all 4" Dynascopes........**$17.50**
Cat. #CS-47 to fit all 4¾" O.D. tubes..**$18.95**
Cat. #CS-67 to fit custom 6" Dynascope and 7¼" O.D. tubes.......................**$19.95**

Catalog F, describing other accessories and parts, cheerfully sent on request. Satisfaction guaranteed, or money refunded. All items sent postpaid. We pay all postage costs. No shipping, crating or packing charges. Send check, cash, or money order for immediate delivery.

Paraboloidal Mirrors

The most important part of a reflector telescope is the precisely figured mirror. A mirror with a spherical surface suffers from spherical aberration, so it must be altered to a paraboloid to focus all the light rays in each bundle to the same point. Considerable skill is required to parabolize a fine mirror properly. Criterion Custom mirrors are made of the best pyrex glass, selected for freedom from internal stress and strain, and of the correct thickness for each size, parabolized by craftsmen and tested by Ronchi and Foucault tests, as well as by diffraction rings and resolution of double stars. They are aluminized and overlaid with zircon quartz. Each is guaranteed unconditionally, and to perform to the limit of resolution for its size.

4" pyrex, f.l. approx. 40"	**$31.00**
6" pyrex, f.l. approx. 54"	**$45.00**
8" pyrex, f.l. approx. 64"	**$89.00**
10" pyrex, f.l. approx. 80"	**$179.00**
12" pyrex, f.l. approx. 96"	**$275.00**

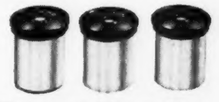
A tolerance of 5% in focal length is customary. A deposit of ⅓ is required with orders for 8" to 12" mirrors.

Reflecting Telescope Mirror Mounts

Mounting the mirror to your scope correctly is most important. Criterion mounts are especially well designed, and are made of cast aluminum with brass mounting and adjustment screws. One section fits tube, other section holds mirror. Alignment accomplished by three spring-loaded knurled adjusting nuts. Outer cell designed to fit into or over your tube. Sufficient space left between the two cells. All drilled and tapped. Complete with holding clamps, springs, nuts, etc. Ready for use. Will prevent vibration and hold alignment once set. Will hold mirror without distortion of surface figure.

3"	**$3.00**	6"	**$6.00**
4"	**3.50**	8"	**12.50**
5"	**4.00**	10"	**14.75**

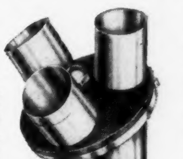
Complete Eyepieces



Finest quality. They are precision machined, mounted in standard 1¼" outside diameter barrels; ⅞" O.D. also available at no extra cost. Can be taken apart for cleaning. Designed to give sharp flat field clear to edge.

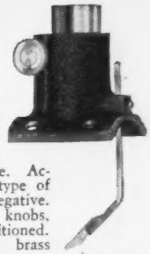
Huygens 18-mm. f.l. (¾")	**$ 7.50**
Kellner 9-mm. f.l. (⅜")	**7.90**
Kellner 7-mm. f.l. (9/32")	**8.50**
Kellner 12.7-mm. f.l. (½")	**9.50**
Orthoscopic 6-mm. f.l. (¼")	**12.50**
Orthoscopic 4-mm. f.l. (5/32")	**14.50**

Revolving Turret



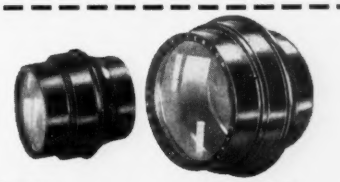
The Criterion Revolving Turret holds three eyepieces so that, as desired, the power of the telescope can be changed by merely turning the turret to a different ocular. Click stop insures positive and accurate positioning of each eyepiece. Turret holds eyepieces of standard 1¼" outside diameter. Fits into the holder of any refractor or reflector telescope that uses 1¼" eyepieces. Requires no alteration or adjustment and can be attached as easily as putting eyepiece into scope. Made of brass and aluminum with polished chrome-plated barrels.
Cat. #SRT-350..................**$14.50**

Rack-and-Pinion Eyepiece Mount



The most mechanically perfect focusing is by rack and pinion. This mount takes standard 1¼" eyepieces. Full 3½" of travel — more than ever before. Accommodates almost any type of eyepiece — positive and negative. Two knurled focusing knobs, variably tensioned and positioned. Solid cast-metal sliding brass tube — close tolerance prevents looseness. Mount aligns itself to any type tube. Four mounting holes, nuts and bolts included. Eye mount has square-rod-type diagonal holder which prevents loose alignment and vibration. Rod tempered to minimize temperature changes. Adjustable for 3" to 8" scopes, also 12" scopes if so specified at no extra cost. Order one or more of the complete eyepieces described below at the same time you send for this rack-and-pinion device, which accommodates any of our eyepieces perfectly.
Cat. #SU-38 **$7.95 postpaid**

New Model Eyepiece Mount
Same features as above but has wider base that is contoured to match the curve of a 7" to 8" diameter tube. Makes professional appearance. Furnished without Diagonal Rod #SU-9R **$9.95**
Diagonal Rod — Cat. #SU-9R........**$1.00**



Custom Achromatic Objectives and Sunshade

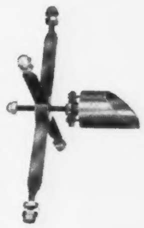
Criterion Custom Series Achromatic Objectives are of the highest precision quality, tested and approved and acclaimed to be superb in every respect. Equipped with sunshade and dewcap.

FEATURES

- Perfect color correction at the wave lengths of the C and F spectral lines, best for visual observing. Scientifically designed, corrected by master craftsmen.
- Delicately hand-corrected to fullest minimization of residuals, and to eliminate spherical aberration.
- Air-spaced to very critical optical formula.
- Magnesium-fluoride coated on all surfaces for maximum light transmission.
- Cell engraved with effective focal length and completely threaded.
- Sunshade extension with dewcap on all sizes.

Cat. #	Clear Aperture	Focal Length	Price
S-210	60 mm. (2.4")	910 mm. (35.8")	**$19.95**
S-220	3"	1250 mm. (49.2")	**52.00**
S-230	4"	1600 mm. (62.9")	**95.00**

Four-Vane Diagonal Holders



Criterion 4-vane diagonal mountings are fully adjustable, will hold elliptical diagonals in perfect alignment. Made of brass, chemically blackened. Precision adjusting screws center flat and vary its angle so that primary and secondary mirrors can be set in perfect alignment. Thin vanes with special adjustable studs.

Cat. #	Minor-Axis Size	For Tubes	Price
S-51	1.25"	6½" to 7½"	**$10.00**
S-52	1.30"	6½" to 7½"	**10.00**
S-53	1.50"	8½" to 9½"	**10.00**
S-54	1.75"	9½" to 10½"	**12.50**
S-55	2.00"	11" to 11½"	**14.95**
S-56	2.50"	Specify tube I.D.	**19.95**

CRITERION MANUFACTURING CO.

Manufacturers of Quality Optical Instruments

Dept. STP-18, 331 Church St., Hartford 1, Conn.

CELESTIAL CALENDAR

Universal time (UT) is used unless otherwise noted.

OBSERVABLE ALGOL MINIMA

CHECKING whether Algol, the famous eclipsing variable in Perseus, is below normal brightness is a good habit for one who frequently scans the sky. But just what are the chances of finding Beta Persei at or near minimum brightness?

The minima occur every two days, 20 hours, 49 minutes, usually on one date in three. About 10 hours are required for the change from magnitude 2.2 to 3.5 and back again. During the first two and last two hours the loss in light could escape a casual glance, so for only one-quarter of a day would the change attract attention. Thus, Algol is noticeably faint about 1/12 of the time.

But some minima occur in the daytime, halving the chances even in winter, to about 1/24. Considering cloudy nights, the expectation of casually finding Algol faint is, therefore, very poor, and predictions of minima are practically essential to the observer.

As the listing here shows, the most convenient times this month for American amateurs to see Algol dimmed will be during the minima predicted for the 9th at 2:38 a.m. Eastern standard time; the 11th, at 11:27 p.m.; and the 14th, at 8:16 p.m.

NOVEMBER METEORS

Beginning in late October, the Taurid meteor shower reaches its maximum during the first week of November. On the 6th a single observer may see up to 15 meteors per hour, the radiant then being located in western Taurus. The moon, only a week past new phase, should not interfere seriously with observations of these meteors.

For the Leonid shower, with maximum on November 17th, observing conditions are very unfavorable, as it is shortly after full moon. W. H. G.

MINOR PLANET PREDICTIONS

Parthenope, 11, 9.6. November 28, 6:03.9 +18-25. December 8, 5:54.6 +18-30; 18, 5:44.0 +18-39; 28, 5:33.4 +18-49. January 7, 5:24.1 +19-02; 17, 5:17.0 +19-17. Opposition on December 18.

After the asteroid's name are its number and the magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1950.0) for 0^h Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

MINIMA OF ALGOL

November 3, 14:01; 6, 10:50; 9, 7:38; 12, 4:27; 15, 1:16; 17, 22:05; 20, 18:54; 23, 15:43; 26, 12:32; 29, 9:21.

December 2, 6:10; 5, 2:59; 7, 23:48.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of least brightness.

UNIVERSAL TIME (UT)

TIMES used in Celestial Calendar are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown. For example, 6:15 UT on the 15th of the month corresponds to 1:15 a.m. EST on the 15th, and to 10:15 p.m. PST on the 14th.

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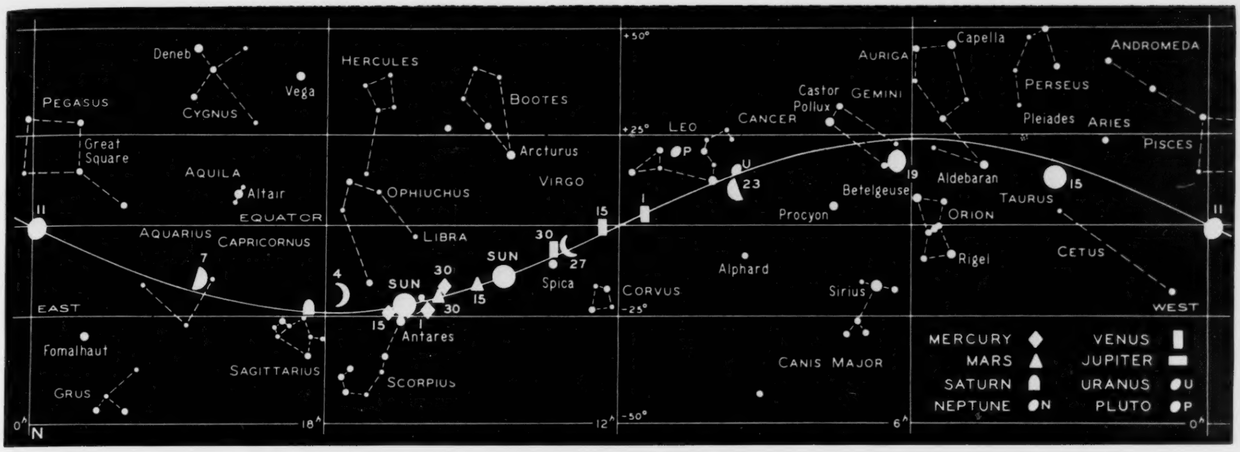
Classified advertising costs 30 cents a word, including address; minimum charge, $4.00 per ad. Only one *for sale* ad per issue for each advertiser. *Remittance must accompany order.* Insertion is guaranteed only on copy received by the 20th of the second month before publication; otherwise, insertion will be made in next issue. We cannot acknowledge classified ad orders. Sky Publishing Corporation assumes no responsibility for statements made in classified ads, nor for the quality of merchandise advertised. Write Ad Dept., *Sky and Telescope,* Harvard Observatory, Cambridge 38, Mass.



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown. All positions are for 0^h Universal time on the respective dates.

Mercury reaches greatest eastern elongation on November 3rd, 23° 33′ from the sun, and may be seen very low in the southwest for about a week before and after this date. The planet is poorly placed for observation at this elongation, however, and sets about an hour after the sun. Inferior conjunction is on the 24th.

Venus attains greatest western elongation, 46° 37′ from the sun, on November 12th. It is a brilliant object, magnitude −4.0, rising about four hours before sunup. On the 11th its disk will be half illuminated and 24″.7 in diameter. The moon will be very near Venus on the morning of the 27th, conjunction occurring at 2:10 Universal time, with the planet 37′ north if viewed from the center of the earth. An occultation will be seen from South Africa and Australasia.

Mars is in the morning sky, but too near the sun to be observed this month.

Jupiter may be seen the first week in November, low in the southwest. On the 1st it is magnitude −1.3, setting about 1½ hours after the sun. Mercury and Jupiter will be in conjunction on the 7th, with the former about 3½° south.

Saturn, of the 1st magnitude, is in Sagittarius, low in the southwest during the early evening. A telescope will reveal its disk, 13″.8 in polar diameter, and the rings, 34″.8 in extent. The moon will pass 4½° north of Saturn on the 4th.

Uranus, in western Leo, rises about midnight local time. Binoculars will reveal this 6th-magnitude object, at right ascension $9^h\ 33^m.9$, declination +15° 12′ (1950 co-ordinates) on November 14th, the time of its western quadrature. Uranus is stationary in right ascension on the 27th, and then begins retrograde (westward) motion among the stars.

Neptune is too close to the sun to be seen this month.

W. H. G.

MOON PHASES AND DISTANCE

First quarter	November 7, 13:23
Full moon	November 15, 9:42
Last quarter	November 23, 13:03
New moon	November 30, 8:46
First quarter	December 7, 2:11

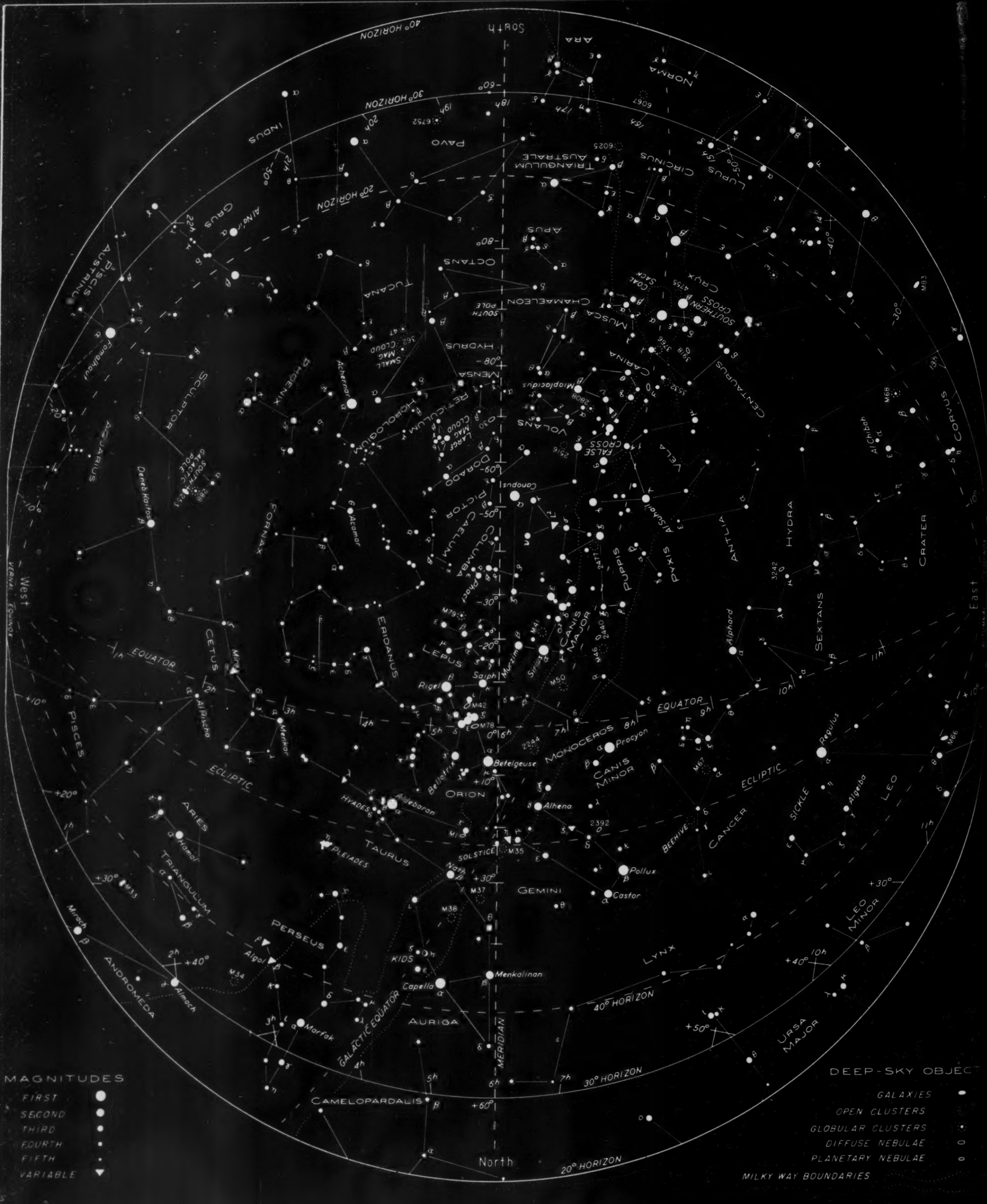
November	Distance	Diameter
Perigee 2, 1^h	223,100 mi.	33′ 17″
Apogee 17, 7^h	252,600 mi.	29′ 24″
Perigee 30, 12^h	221,600 mi.	33′ 30″
December		
Apogee 14, 7^h	252,600 mi.	29′ 24″

VARIABLE STAR MAXIMA

November 2, S Carinae, **100661**, 5.7; 4, T Normae, 153654, 7.4; 7, RS Librae, **151822**, 7.7; 7, RS Cygni, 200938, 7.4; 19, R Sagittarii, **191019**, 7.2; 21, T Herculis, 180531, 8.0; 22, R Cygni, 193449, 7.3; 27, T Aquarii, **204405**, 7.9.

December 1, R Draconis, 163266, 7.6; 5, T Centauri, **133633**, 6.1.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.



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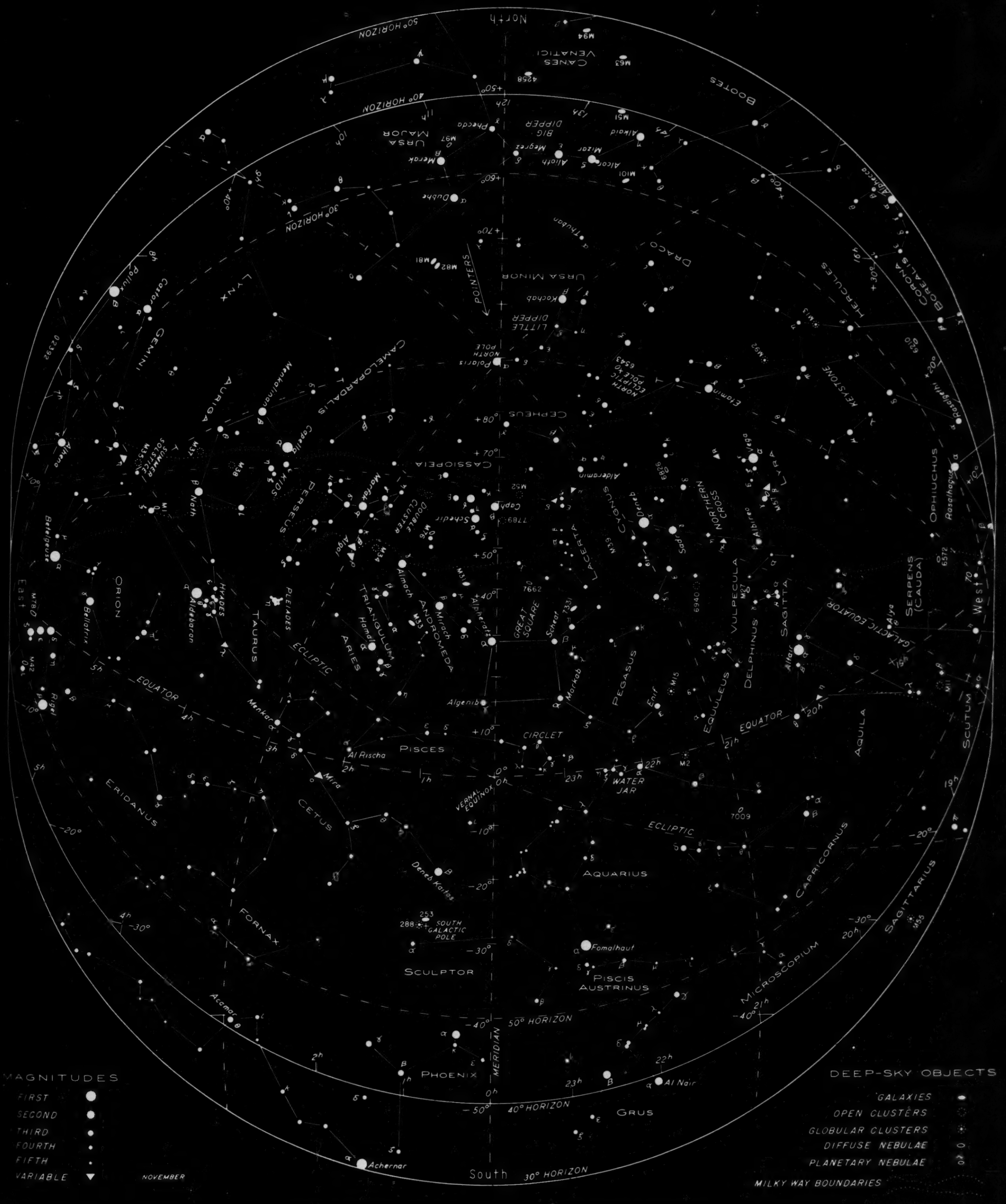
SOUTHERN STARS

The sky as seen from latitudes 20° to 40° south, at 11 p.m. and 10 p.m., local time, on the 6th and 22nd of January, respectively; also, at 9 p.m. and 8 p.m. on February 6th and 21st. For other dates, add or subtract ½ hour per week.

Fifteen 1st-magnitude stars are above the horizon at latitude 30° south at chart time. Fomalhaut is just setting in the southwest, while Regulus is climbing the sky in the east. Orion, a summer constellation south of the Tropic of Capricorn, is almost on the meridian.



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STARS FOR NOVEMBER

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 22nd of November, respectively; also, at 7 p.m. and 6 p.m. on December 7th and 22nd. For other dates, add or subtract ½ hour per week.

Running from east to west and crossing overhead this month, the northern Milky Way is an inspiring sight. Locate the bright constellations in it: Auriga, Perseus, Cassiopeia, Cygnus, and Aquila. Try also Lacerta, little Delphinus, Sagitta, and the faint stars of Vulpecula.

HOW TINSLEY DEVELOPED TWO TELESCOPES IN ONE FOR B. Y. U.

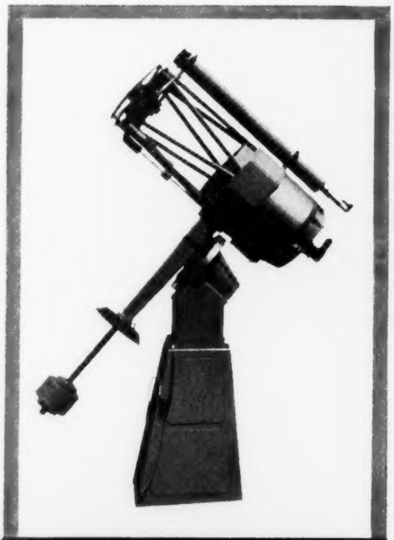
When Brigham Young University's Astronomy Department assigned Tinsley Laboratories to design and manufacture a new telescope for the University, they asked for an instrument that would perform two distinct jobs: 1) student instruction and visual use; 2) wide field photography for advanced research.

Tinsley combined both functions in a single powerful instrument for BYU: a custom-designed 24-inch reflector telescope with a Baker photographic corrector.

The basic Newtonian-Cassegrain design with a 24-inch-diameter f/4 main mirror fulfills BYU's requirements for visual instruction. The Cassegrain, which is f/15, has complete skylight shielding.

With the Baker photographic corrector the telescope performs its second job with unusual versatility. The corrector permits photography of a seven degree field—a picture equal in width to 14 full moon photos laid side-by-side!

BYU's telescope, now in operation at Provo, Utah, is an example of the precision craftsmanship and exacting specifications which have built Tinsley's reputation as the leader in custom optical instrumentation.



TINSLEY
LABORATORIES, INC.
2526 Grove Street, Berkeley 4, Calif.

PRINTED BY WELLESLEY PRESS, INC.

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